WAR DEPARTMENT TECHNICAL MANUAL

TM 5-252

This manual supersedes TM 5-9500, Principles of Modern Excavation and Equipment, 11 August 1942.

USE OF

ROAD AND AIRDROME

CONSTRUCTION EQUIPMENT

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For explanation of symbols, see FM 21-6.

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CONTENTS

This manual supersedes TM 5–9500, Principles of Modern Excavation and Equipment, 11 August 1942.

CHAPTER 1

GENERAL

Section I. INTRODUCTION

1. PURPOSE. This manual is written for officers and noncommissioned officers responsible for road and airdrome construction. It tells how to use available equipment and personnel most efficiently, and how to plan, schedule, and supervise specific jobs.

2. SCOPE. The scope of this manual includes:

a. Basic construction considerations.

b. Basic construction operations, and equipment used in these operations.

c. Characteristics and capabilities of specific pieces of equipment, guides to supervising their operation, and aids for obtaining increased work output.

d. Capabilities and use of labor.

e. Estimation of work and equipment required, work planning and scheduling, and supervision of construction of improved roads and airdromes.

f. Estimation of work and assignment and use of equipment in construction of pioneer roads and advanced landing fields.

3. REFERENCES. Operations and organization of engineer units are described in FM 5–5 and FM 5–6. Tactical and technical information is available in FM 5–10 for roads and in TM 5–255 for airdromes. FM 5–35 includes reference data for road and airdrome construction. Other manuals covering related technical subject matter are:

a. Camouflage, Basic Principles, FM 5–20.

b. Explosives and Demolitions, FM 5–25.

c. Motor Transport, FM 25–10.

d. Carpentry, TM 5–226.

e. Topographic Drafting, TM 5–230.

f. Surveying, TM 5–235.

g. Construction of Buildings and Utilities in the Theater of Operations, TM 5–280 and TM 5–281.

h. Rigging and Engineer Hand Tools, TM 5–225.

i. Water Supply and Water Purification, TM 5–295.

Section II. BASIC CONSIDERATIONS

4. GENERAL. The considerations below are basic in assigning, operating, and managing engineer equipment and personnel in road and airdrome construction.

5. JOB REQUIREMENTS. Job requirements are determined by:

a. Type of job.

b. Dimensions of road or airdrome.

c. Quantities of excavation and construction materials used.

d. Technical specifications.

e. Time allotted.

6. TRANSPORTATION FACILITIES. Transportation facilities for delivering troops, equipment, and material to the work site depend on the location of the site with respect to:

a. Engineer depots from which materials and equipment are obtained.

b. An adequate network of roads and railroads for the transport of materials and equipment.

c. Airdromes and advanced landing fields for the supply of airborne materials and equipment.

d. Harbors or beaches for the supply of water-borne materials and equipment.

7. TIME. Time is a basic factor in construction operations in theaters of operations. Failure to complete a project within the time allotted may delay tactical operations and result in failure of the over-all tactical plan. Economy of time can be attained only by careful, detailed, and accurate planning and scheduling of operations, materials, equipment, and personnel.

8. SITE CONDITIONS. Site conditions directly influence the lay-out of the project and the planning and scheduling of construction operations.

a. Topography. Topography controls volume of cut and fill, length of hauls, layout of materials plants (fig. 1), and construction of communication facilities.

b. Soil and geology. The types of materials excavated, sources of embankment materials, and types of equipment employed for different operations are determined by soil and geologic conditions. Soil and rock materials are described throughout this manual as light, medium, and heavy soils, consolidated material, or rock on the basis of their excavation characteristics. (See table I.) Occasional reference is also made to the Corps of Engineers (Casagrande) classification system which is expressed in terms of *plasticity* and *gradation*. (See TM 5–255 and FM 5–10).

c. Drainage. Drainage conditions control wetness of materials to be excavated, amount of work necessary for preliminary and final drainage, and effect of rains which occur during the construction period.

d. Vegetation. Vegetation determines the difficulty of clearing and grubbing and, to some extent, the accessibility of work areas.

9. WEATHER. a. Long-range planning of construction activities must take into consideration normal seasonal fluctuations in climate. When tactical plans permit, construction work should be done during the best seasons.

b. Normally, hot, dry weather is ideal for construction work. Continued rain interferes with nearly all phases of construction and in

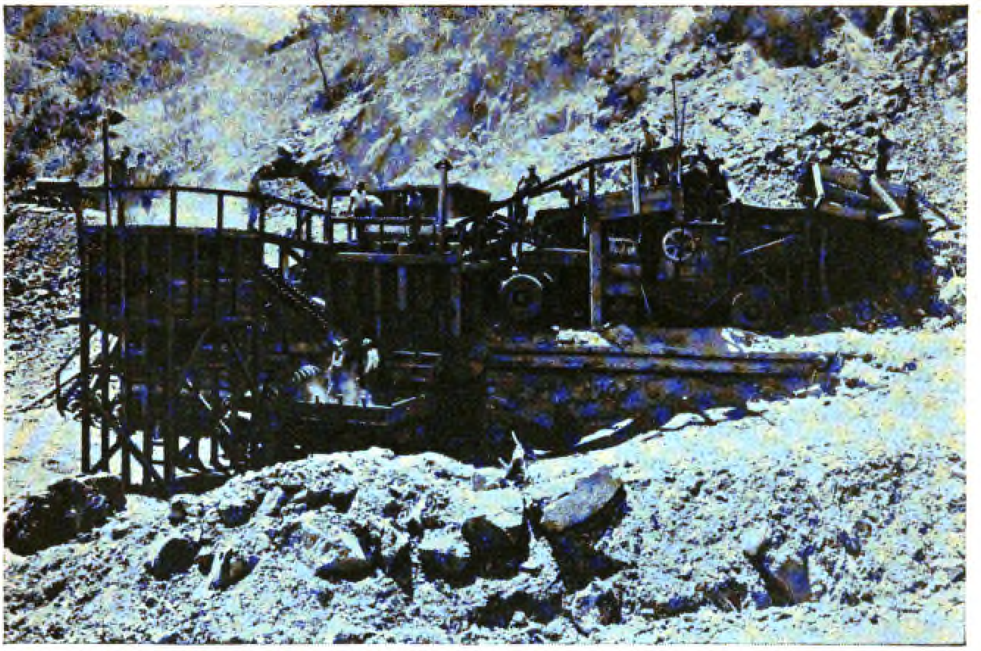


Figure 1. Crushing and screening plant located on a hillside to take advantage of gravity in handling and loading materials.

particular hinders earth-moving operations in plastic soils. (See fig. 2.) In freezing temperatures, special equipment is required for handling soils and aggregates and extra maintenance of all machinery is necessary. (See fig. 3.)

Figure 2. Heavy equipment working on a jungle road in mud caused by tropical rains.

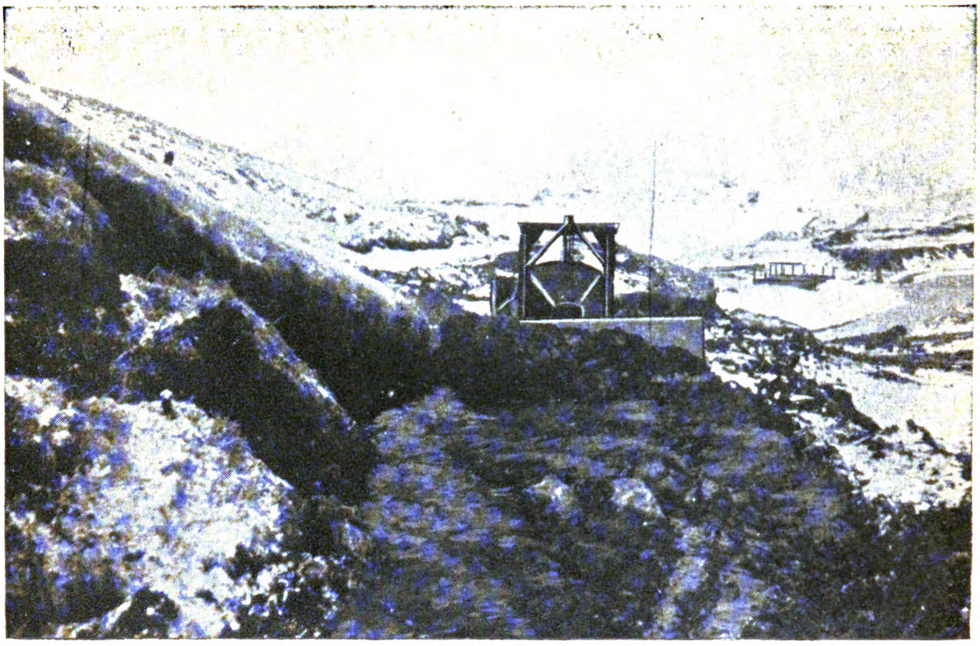


Figure 3. Angledozer building pioneer road under arctic weather conditions. Freezing temperatures and frozen soil and muck all create serious equipment maintenance problems.

10. ENEMY INTERFERENCE. In planning a construction job, the possibility of enemy interference must be taken into account. Plans are made to:

a. Disperse and camouflage equipment for protection against enemy reconnaissance, artillery fire, or aerial observation and bombing. (See fig. 4.)

b. Organize local security against assault by parachute, airborne, or ground troops.

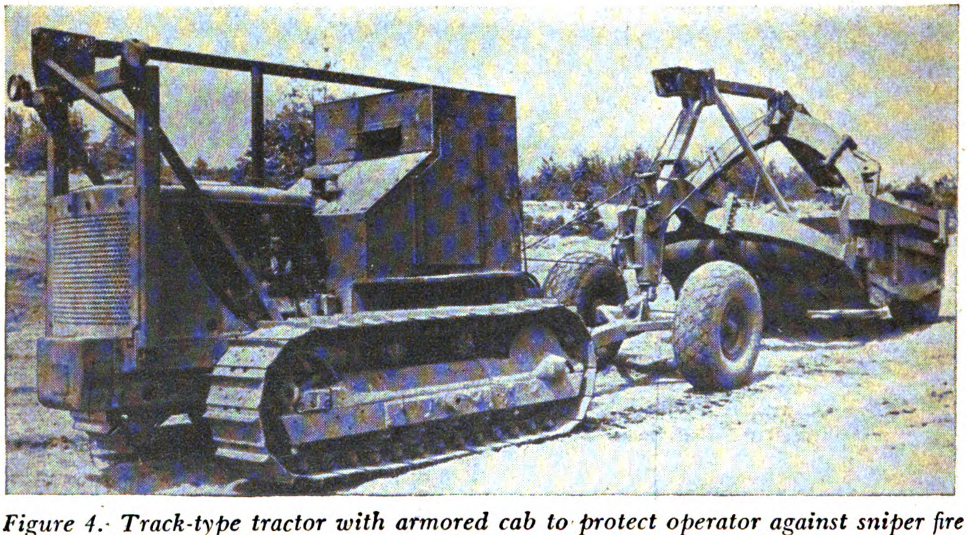


Figure 4. Track-type tractor with armored cab to protect operator against sniper fire and shell and bomb fragments. Tractor is towing an 8-cubic-yard scraper of bolted construction to facilitate disassembly and reassembly when transported by air.

c. Organize observation, alarm, and communication systems.

d. Destroy equipment when capture by the enemy is imminent.

11. USE OF LOCAL RESOURCES. **a.** In military construction, every effort is made to take full advantage of available local materials. Materials such as coral, caliche, volcanic cinders, and iron ore require special handling; this must be taken into account in assigning equipment and scheduling operations.

b. Local labor (fig. 5) can often be used to supplement troops and equipment and to release trained men for technical jobs. Use of local labor increases the risks of sabotage and espionage, and appropriate precautions must be taken. It also exerts considerable influence on the assignment of equipment and the scheduling of operations, since local labor often performs by hand tasks normally accomplished by machinery and natives should be allowed to use tools with which they are familiar.

c. Local construction and transportation equipment and farm machinery can often be adapted to road and airdrome construction operations. (See fig. 5.)

d. Existing local facilities, such as buildings, roads, quarries, gravel pits, and developed water resources, are used whenever practicable.

Figure 5. Native labor and local equipment working on a landing-strip excavation. Engineer troops supervise such operations.

12. SUPPLEMENTARY EQUIPMENT. Jobs involving large volumes of work sometimes require additional items of engineer equipment. Extra units of equipment or machines of larger capacity are obtained by requisitions on engineer depots. Units of standard engineer equipment, with operators and crews, can frequently be obtained on a daily dispatch basis by loan from engineer light equipment companies or neighboring engineer units.

CHAPTER 2

CONSTRUCTION OPERATIONS AND ASSIGNMENT OF EQUIPMENT

13. APPLICATION OF EQUIPMENT TO CONSTRUCTION OPERATIONS. Practically every operation in the construction of roads and airdromes can be performed by several types of equipment, but under a given set of conditions a specific type of equipment will be most efficient. Table I defines road and landing-strip construction operations, lists various pieces of engineer equipment which can be used in each operation, and sets forth their limitations and proper application.

Table I. Construction operations and assignment of equipment.

Work Item / Construction Operation	Equipment	Reference to secs. of ch. 3	Application
1. CLEARING AND GRUBBING. Removing all trees, stumps, brush, logs, windfalls, other vegetation, and boulders.			
a. Cutting grass and weeds.	(1) (*a*) Grader, road, motorized.	VII	Used to cut grass and weeds and to remove dead vegetation.
	(*b*) Grader, road, towed (tractor as prime mover).	VII and II	
	(2) Mower, tractor-drawn (tractor as prime mover).	XIV and II	Used to cut extremely heavy growths of weeds and grass.
b. Light clearing. Removing scattered clumps of brush and small trees or occasional large trees or boulders.	(1) Dozer, tractor-mounted (including tiltdozer, angledozer, or bulldozer blades).	III and II	Where terrain permits use of heavy equipment, D7 tractor equipped with dozer blade and rear-mounted towing winch (not the power-control unit) is best for clearing trees and stumps with shallow roots. (See fig. 6.) The bulldozer is the most satisfactory blade for this work, the angledozer is second choice. The winch assists in rapid removal and piling of material.

	(2) Saw, chain, portable.	XIV	Used to fell trees and to cut fallen trees into logs for hauling and piling. (See fig. 7.)
	(3) Explosives (air compressor and pneumatic tools, or hand tools as auxiliary equipment).	IX and sec. III, ch. 4	Used to remove stumps, trees, and large boulders too large for a dozer.
c. Medium and heavy clearing. Removing heavy brush, trees, or large boulders, which cover more than 25 per cent of the area.	(1) (*a*) Winch, tractor-mounted, general-utility (Jacques tree and stump puller). (*b*) Power saw, tractor-mounted (Jacques clearing saw).	XIV	Best machine for rapid clearing of deep-rooted, heavy growth encountered in bottom lands, swamps, and jungles. Also best in terrain too broken and rough to maneuver heavy construction equipment. Power saw used to cut standing or felled timber of up to 50-inch diameter.
	(2) Winch, tractor-mounted, single-drum, nonreversible (Evans tree and stump puller).	XIV	Same as general-utility winch.
	(3) Dozer, tractor-mounted (including tiltdozer, angledozer, or bulldozer blades).	III and II	When clearing winches are not available, a D6, D7, or D8 tractor equipped with dozer blade and towing winch must do the bulk of the work. It is necessary auxiliary equipment for piling, skidding, and clean-up. (See figs. 8 and 9.)
	(4) Saw, chain, portable.	XIV	See work item 1*b* (2).
	(5) Explosives (air compressor and pneumatic tools, or hand tools as auxiliary equipment).	IX and sec. III, ch. 4	See work item 1*b* (3).
2. LIGHT STRIPPING. Removing and disposing of leaves, twigs, and grass, sod, and organic soil which covers desirable material.	(1) Dozer, tractor-mounted (including tiltdozer, angledozer, or bulldozer blades).	III and II	Best machine for removing vegetation and organic soil when opening borrow and gravel pits, cuts for roads and landing strips, and when preparing foundations for road, landing strip, and dike embankments. Especially useful on rough, uneven ground when haul distances are less than 200 feet.

Table I. Construction operations and assignment of equipment. Contd.

Work Item / Construction Operation	Equipment	Reference to secs. of ch. 3	Application
	(2) (*a*) Scraper, road, motorized.	IV	Same applications as dozer but most effective on fairly even ground when haul distances exceed 200 feet. Will not handle muck.
	(*b*) Scraper, road, towed (tractor as prime mover).	IV and II	
	(3) (*a*) Grader, road, motorized.	VII	Does same work as dozer or scraper. Used primarily when waste material can be windrowed along stripped area.
	(*b*) Grader, road, towed (tractor as prime mover).	VII and II	
	(4) Rooter, road, towed (tractor as prime mover).	VIII and II	Breaks roots and frozen material which bind vegetation and organic soil.
3. DITCHING AND DIKING. Construction of open V-shaped or trapezoidal drainage channels and dikes or levees for diversion and interception of surface water.	(1) (*a*) Grader, road, motorized.	VII	Best machine for excavating open ditches and erecting small dikes in light or medium soil without rocks or roots. Material is windrowed or spread to one side or the other. (See fig. 10.)
	(*b*) Grader, road, towed (tractor as prime mover).	VII and II	
	(2) Dozer, tractor-mounted (including tiltdozer, angledozer, or bulldozer blades).	III and II	Best suited for excavating sump pits and open ditches, building dikes, levees, and small dams in heavy soil containing many rocks and roots. (See fig. 11.)
	(3) Power shovel, dragline, or clamshell, truck- or crawler-mounted (supplemented with dump trucks for hauling).	V	Used to excavate large ditches required in channel changes, stream diversion, and main collecting channels. Greatest efficiency attained when material can be cast to either side. Dragline or power shovel especially useful to dig out root masses, boulders, and shattered rock. Shovels used where excavation is above working grade; draglines and clamshells where excavation is below working grade. (See fig. 12.)

	(4) Plow, moldboard-type, tractor-drawn (tractor as prime mover).	VIII and II	Useful in excavating shallow ditches and constructing small dikes where unconsolidated soil does not contain large rocks or roots.
	(5) Rooters, road, towed (tractor as prime mover).	VIII and II	Essential for breaking roots and loosening compacted soil before ditch excavation begins.
	(6) Explosives (air compressor and pneumatic tools, or hand tools as auxiliary equipment).	IX and sec. III, ch. 4	Essential for excavating drainage ditches through rock formation; helpful in clearing ditches in boggy, saturated soils.
4. PUMPING. Lifting and removing water by mechanical methods.	Pumps, centrifugal or diaphragm.		Used to remove water from sumps, structure excavations, and low areas which cannot readily be drained by ditching. (See fig. 13.)
5. TRENCHING. Excavating deep, narrow ditches with vertical or near vertical sides.	(1) Ditching machine, ladder-type, crawler-mounted.	XIV	Best machine for excavating trenches in light or medium soils containing no large roots or boulders.
	(2) Power shovel, trench hoe, dragline or clamshell, truck- or crawler-mounted (supplemented with dump trucks for hauling).	V	Used to excavate wide, moderately deep trenches in all soils containing large roots or boulders.
6. BACKFILLING. Replacing excavated material in a trench after a drain has been placed, or placing it against a completed structure.	(1) Dozer tractor-mounted (including tiltdozer, angledozer, or bulldozer blades).	III and II	Best for backfilling ditches, pits, and other excavations. (See fig. 14.)
	(2) (*a*) Grader, road, motorized. (*b*) Grader, road, towed (tractor as prime mover).	VII and II	Effective for side-casting windrowed backfill material into an open ditch.
	(3) Loader, bucket, tractor-mounted.	XIV	Useful in backfilling small yardages.

Table I. Construction operations and assignment of equipment. Contd.

Work Item / Construction Operation	Equipment	Reference to secs. of ch. 3	Application
7. EXCAVATION AND EMBANKMENT. Includes digging, loading, hauling, and dumping of various types of soil and rock material.			
a. Light and medium soils. Light soil can be excavated without preliminary loosening. Sand is an example. Medium soil rarely requires preliminary loosening when excavating equipment is used. Ordinary agricultural soil is an example.	(1) (*a*) Scraper, road, motorized. (*b*) Scraper, road, towed (tractor as prime mover).	IV and II	Best machine for moderate hauls, such as road and landing-strip embankments built from distant cuts or borrow pits. (See fig. 15.)
	(2) Dozer, tractor-mounted (including tiltdozer, angledozer, or bulldozer blades).	III and II	Best unit where haul is not required. Used for sidehill cuts for roads (fig. 16), embankments built from adjacent borrow pits, stripping overburden from gravel or other desirable material, and excavation and levelling for culvert, bridge, and other foundations. Particularly useful in stripping muskeg, muck, and similar materials from road and landing-strip foundation areas.
	(3) (*a*) Grader, road, motorized. (*b*) Grader, road, towed (tractor as prime mover).	VII and II	Best machine for constructing shallow road embankments across flat or gently rolling land composed of light or medium soil. (See fig. 17.) Most efficient when fill does not exceed 1½ feet. Embankment material obtained by cutting longitudinal drainage ditches at side.
	(4) Power shovel, truck- or crawler-mounted (supplemented with dump trucks for hauling).	V	Most useful in two types of deep-face excavation: (1) Excavation in which material is cast directly from cut to fill. Examples are sidehill cuts for roads and stripping thick overburden. (2) Excavation involving long hauls by dump trucks.

			Examples are embankments built from distant cuts or borrow pits (fig. 18) and excavation and leveling for culvert and bridge foundations.
	(5) Dragline or clamshell, truck- or crawler-mounted (supplemented with dump trucks for hauling).	V	Dragline best for excavation requiring long reach and considerable latitude in spotting hauling equipment. Can dig below work level or under water. Particularly suited to digging from borrow pits, excavating muck, muskeg, and other saturated materials. (See fig. 19.) Clamshell used in cleaning out holes or in cramped quarters, such as pier foundations, gravel pits, or deep borrow pits. Also for excavations requiring high lift, such as digging gravel from pit or stock pile and placing it in bin or screening plant.
	(6) Plow, moldboard-type, tractor-drawn, and loader, bucket, tractor-mounted (supplemented with dump trucks for hauling).	VIII and XIV	Earth loosened with a plow may be loaded by the tractor-mounted loader. Used to handle small volumes in confined quarters such as sump pits and small foundations. (See fig. 20.) Tractor-mounted loader can loosen only uncompacted sands or gravels and light soil.
b. Heavy material. Includes stiff clay, compact but uncemented gravel, and similar materials.	(1) (*a*) Scraper, road, motorized (tractor as pusher). (*b*) Scraper, road, towed (tractors as prime mover and as pusher). (*c*) Scraper, road, motorized (tractor as pusher) and rooter, road, towed (tractor as prime mover).	IV and II	Extra loading time is often required for scraper to load material loosened by a rooter. In such a case, dispense with rooter and use extra pusher tractor to loosen and load material. (See fig. 21.)
	(*d*) Scraper, road, towed (tractor as prime mover) and rooter, road, towed (tractor as prime mover).	VIII	

Table I. Construction operations and assignment of equipment. Contd.

Work Item	Construction Operation	Equipment	Reference to secs. of ch. 3	Application
		(2) Dozer, tractor-mounted (including tiltdozer, angledozer, or bulldozer blades).	III and II	See work item 7*a* (2) above.
		(3) (*a*) Grader, road, motorized, and rooter, road, towed (tractor as prime mover).	VII and II	Used to build shallow road embankments across flat land of heavy material after soil has been loosened by rooters.
		(*b*) Grader, road, towed (tractor as prime mover), and rooter, road, towed (tractor as prime mover).	VIII	
		(4) Power shovel, truck- or crawler-mounted (supplemented with dump trucks for hauling).	V	See work item 7*a* (4) above. Power shovel loses 25% to 50% of its maximum work output in this material.
		(5) Dragline or clamshell, truck- or crawler-mounted (supplemented with dump trucks for hauling).	V	See work item 7*a* (5) for applications. These units lose 25% to 60% of their maximum work output in this material.
c.	*Consolidated material.* Soil and rock particles partly cemented together. Is difficult to dig, requiring use of rooters or explosives. Hard pan and shale are examples.	(1) (*a*) Rooter, road, towed (tractor as prime mover).	VIII and II	All material must be loosened by rooters or explosives before loading. (See fig. 22.)
		(*b*) Explosives (air compressor and pneumatic tools, or hand tools as auxiliary equipment).	IX and sec. III, ch. 4	
		(2) Dozer, tractor-mounted (including tiltdozer, angledozer, or bulldozer blades).	III and II	Best unit for moving, dumping, and spreading loosened material when haul distance is less than 300 feet. Used to pile the material for pick up by power shovels or to load directly into trucks through chutes and other loading structures.

	(3) Power shovel, dragline or clamshell (supplemented with dump trucks for hauling).	V and VI	See work item 7*a* (4) above for applications. These units lose 35% to 65% of their maximum efficiency in this material.
	(4) (*a*) Scraper, road, motorized. (*b*) Scraper, road, towed (tractor as prime mover).	IV	Scrapers can be used in this material after it has been broken up by rooting or blasting but lose a large proportion of their maximum efficiency.
d. Rock.	(1) Explosives (including air compressor and pneumatic tools, or hand tools as auxiliary equipment).	IX and sec. III, ch. 4	Necessary to break up rock for handling by excavation machinery.
	(2) Power shovel, truck- or crawler-mounted (supplemented with dump trucks for hauling).	V and VI	See work item 7*a* (4) above for applications. Loses 35% to 65% of its maximum efficiency in this material, but is the best machine for loading such material into hauling units.
	(3) Dozer, tractor-mounted (including tiltdozer, angledozer, or bulldozer blades).	III and II	Used to push this material for short distances to fills or to piles from which power shovels can load.
	(4) Dragline or clamshell, truck- or crawler-mounted (supplemented with dump trucks for hauling).	V and VI	These machines lose most of their effectiveness in this material. Clamshell used to load or cast boulders that can be grasped by the jaws.
e. Structure excavation. Removing soil and rock material from small and confined foundation areas.	(1) Dozer, tractor-mounted (including tiltdozer, angledozer, or bulldozer blades).	III and II	If work space is available, is best tool for excavation required in construction of bridges, culverts, chutes, and aggregate bins.
	(2) Loader, bucket, tractor-mounted.	XIV	Best machine for loading into trucks from confined structural excavation areas. All except light, loose soils must be loosened by other tools.
	(3) Auger, earth trailer-mounted (truck as prime mover).	XIV	Used in light, medium, or heavy soils not containing boulders or large roots to dig holes for poles, posts, and exploration. (See fig. 23.)
	(4) Pneumatic tools with air compressor and hand tools.	IX	Best for heavy or consolidated materials in small confined areas.

Table I. Construction operations and assignment of equipment. Contd.

Work Item Construction Operation	Equipment	Reference to secs. of ch. 3	Application
8. SPREADING. Distribution of fill and base-course materials into layers of uniform thickness.	(1) (*a*) Scraper, road, motorized. (*b*) Scraper, road, towed (tractor as prime mover).	IV and II	Best machine for dumping and spreading in thin layers as required for road and landing-strip embankments. (See fig. 24.)
	(2) (*a*) Truck, dump. (*b*) Truck, cargo.	VI	Used to dump and distribute all materials for spreading. (See fig. 25.)
	(3) Dozer, tractor-mounted (including tiltdozer, angledozer, or bulldozer blades).	III and II	Best machine for spreading material, including shattered rock, after dumping from trucks.
	(4) (*a*) Grader, road, motorized. (*b*) Grader, road, towed (tractor as prime mover).	VII and II	Used to spread and windrow material of workable nature, not including shattered rock or boulders. (See fig. 26.)
	(5) Spreader box (towed by dump truck).		Receive material directly from rear of trucks; are used to control rate of spread. Careful control of tailgate will serve same purpose.
9. COMPACTION. Consolidating fill, subgrade, or base-course materials. *a. Mechanical methods.* Include use of machines and explosives.	(1) (*a*) Traffic (tracked and wheeled vehicles).		Careful routing of construction equipment (fig. 27) over thin layers of unconsolidated material will accomplish 50% to 60% of required compaction for high fills and all compaction needed for road fills less than 6 feet deep which are to receive earth or gravel surfaces.
	(*b*) Traffic (tracked vehicles).		Track-type tractor is best for compacting gravel, sand, and poorly graded granular soil having little or no fines.
	(*c*) Traffic (wheeled vehicles).		Kneading action of wheel-type vehicles helps consolidate plastic soils.

	(2) Roller, road, towed, sheepsfoot (track-type tractor as prime mover; use 80-dbhp tractor for 2-drum sheepsfoot roller).	XI and II	Best machine (fig. 28) for compacting all plastic soils effective on most base-course materials containing soil binder; can be used on layers of loose, well-graded soils not over 9 inches thick. Will not compact broken rock, gravel, sand, or poorly graded granular soil having little or no fines.
	(3) (*a*) Roller, road, towed, wheeled, rubber tired, 13-tires (rubber-tired wheeled tractor or truck as prime mover). (*b*) Roller, road, towed, smooth-drum, 1- to 3-ton (rubber-tired wheeled tractor or truck as prime mover). (*c*) Roller, road, gas-engine-driven, 3-wheel, 10-ton. (*d*) Roller, road, gas-engine-driven, two-axle, tandem, 5- to 8-ton.	XI and II	Rubber-tired, three-wheel, and tandem rollers are used for compacting thin layers of soil, but are less effective than the sheepsfoot roller. Rubber-tired roller best used for poorly graded soil mixtures and for clay soils of low to medium plasticity. Three-wheel and tandem rollers are used for all types of soil. Base courses of soft crushed stone, limerock, shell, and coral are compacted with the rubber-tired or three-wheel rollers.
b. Tamping. Compacting backfill in trenches or around structures.	Tamper, backfill, pneumatic, with air compressor.	IX	Best unit for compacting backfill around culverts and bridges, in trenches, and other limited areas where rolling equipment cannot be maneuvered.
c. Hydraulic methods.	Pump, centrifugal or pump, diaphragm, with jet pipe or well points.	Sec. IV, ch. 4	When mechanical compaction is not feasible, an embankment may be ponded or jetted. These methods are used only for clean sands or sandy gravels. Ponding consists of flooding the embankment with water held on the surface by dikes; jetting is accomplished by forcing water into holes in the embankment.
10. SCARIFYING AND SHAPING. Scarifying is loosening the upper 6 to 9 inches of subgrade; shaping is bringing the surface to exact grade and cross section.	(1) Grader, road, towed or motorized with scarifier.	VII and II	Best machine for loosening and shaping top layer of a road for landing-strip embankment. (See fig. 29.)
	(2) Cultivator, chisel-tooth (tractor as prime mover).	VIII and II	Used (fig. 30) for scarifying soft, easily penetrated surfaces; requires separate shaping tool.

Table I. Construction operations and assignment of equipment. Contd.

Work Item	Construction Operation	Equipment	Reference to secs. of ch. 3	Application
		(3) Plow, disc, towed-type (tractor as prime mover).	VIII and II	Used to scarify compacted earth fills; requires separate shaping tool.
		(4) Dozer, tractor-mounted (including tiltdozer, angledozer, or bulldozer blades).	III and II	Should not be assigned this work if a grader is available; operator *must* be skillful.
11.	SPRINKLING. Sufficient water is sprinkled on the material to bring it to optimum moisture content before it is compacted.	(1) Distributor, water, truck-mounted, 1000-gallon.		
		(2) Trailer, 1-ton, two-wheel, 250-gallon, water tank (truck as prime mover).	VI	When provided with sprinkler bars, these tanks, and others available from engineer depots, are suitable for sprinkling subgrade before compaction. (See fig. 31.)
		(3) Tank, gasoline and oil, 750-gallon (skid-mounted).		
		(4) Tank, water, canvas with spraybar attachment, 150-gallon (truck-mounted).		
12.	PULVERIZING. Breaking up clods, lumps, and granules into individual grains. The process follows scarifying and shaping.	(1) Harrow, disc (tractor or truck as prime mover).	VIII and II	Best tool for pulverizing well-graded common earth at optimum moisture content. Has enough turning action to rotate layers of material, thus bringing clods to the surface. (See fig. 32.)
		(2) Cultivator, chisel (tractor or truck as prime mover).	VIII and II	Used for breaking clods in clay and compacted soils; also brings clods to the surface.
		(3) Harrow, peg-tooth (tractor or truck as prime mover).	VIII and II	Dragged behind the disc harrow or chisel cultivator to break up small clods as they are brought to the surface.
		(4) Mixer, rotary-tiller, soil-stabilization (tractor, rubber-tired, 30-dbhp, or truck as prime mover).		Designed to pulverize soils for stabilization. (See fig. 33.)

13. MIXING. Incorporating various materials with pulverized foundation material to obtain an ideal admixture.	(1) (*a*) Grader, road, motorized. (*b*) Grader, road, towed (tractor as prime mover).	VII and II	Best machine for mixing previously pulverized materials spread in thin layers.
	(2) Harrow, disc (tractor or truck as prime mover). (3) Cultivator, chisel (tractor or truck as prime mover). (4) Mixer, rotary-tiller, soil-stabilization (tractor, rubber-tired, 30-dbhp, or truck as prime mover).	VIII	Used to accomplish pulverization and mixing in the same operation.
	(5) Plow, moldboard-type, tractor-drawn (tractor as prime mover). (6) Plow, disc, towed-type (tractor as prime mover).	VIII and II	Both used for mixing materials not previously pulverized.
14. QUARRYING. Shattering, scaling, and picking up rock and gravel (see FM 5–10).	(1) (*a*) Rock drill, pneumatic (air compressor).	IX	Best tools to prepare bore holes for explosives and to shatter and scale soft, fractured rock. (See fig. 34.)
	(*b*) Paving breaker, pneumatic (air compressor).	IX	
	(2) Explosives (air compressor and pneumatic tools, or hand tools as auxiliary equipment).	IX and Sec. III, ch. 4	Only satisfactory method of shattering solid rock.
	(3) Dozer, tractor-mounted (including tiltdozer, angledozer, or bulldozer blades).	III and II	Best machine for pushing blasted rock into piles.
15. CRUSHING AND SCREENING. Necessary to convert shattered rock to properly graded aggregate. Graded gravel is produced by screening.	Crushing and screening plant, trailer-mounted.	X	Used to produce clean, graded aggregate for base courses, surfacing, pavements, and structures. (See fig. 35.)

Table I. Construction operations and assignment of equipment. Contd.

Work Item Construction Operation	Equipment	Reference to secs. of ch. 3	Application
16. WASHING. Gravel and crushed rock used as aggregate in concrete and bituminous pavement construction generally require washing to remove silt, clay, and organic material.	Pump, centrifugal or diaphragm.	X	Water must be pumped to the screening and washing plant from nearby streams or other sources.
17. LOADING AND HAULING AGGREGATE. Done in two phases: (1) from quarry to crushing and screening plant, and (2) from plant to stock piles or work site.	(1) Power shovel, dragline, or clamshell, truck- or crawler-mounted.	V	Power shovels are best for removing roughly shattered rock from the quarry and for excavating gravel. Clamshells are best for loading from stock pile to truck or batching plant. (See fig. 36.) Draglines are useful in excavating gravel.
	(2) Dozer, tractor-mounted (including tiltdozer, angledozer, or bulldozer blades).	III and II	Used to pile roughly shattered rock or finished aggregate for loading by other units (fig. 37); also for direct loading when aids such as chutes and traps are provided.
	(3) Loader, bucket, tractor-mounted.	XIV	Used for loading trucks (fig. 37) with finished aggregate from stock piles and for keeping stock piles in shape.
	(4) (*a*) Truck, dump. (*b*) Truck, cargo.	VI	Dump trucks best for hauling aggregate; cargo trucks with expedient beds are satisfactory substitutes.
	(5) (*a*) Scraper, road, motorized. (*b*) Scraper, road, towed (tractor as prime mover).	IV and II	Sometimes used for hauling and spreading aggregates. This is an expedient use.
18. BITUMINOUS SURFACE TREATMENT. *a. Preparation.* Base-course surface or pavement surface is pre-	(1) Sweeper, rotary broom, tractor-mounted.	XIV	Best tool for removing extraneous loose material from surfaces to be treated. (See fig. 38.)

pared by smoothing and sweeping.	(2) Sweeper, rotary broom, towed (tractor as prime mover).	XIV and II	
b. *Spreading bitumen.* Bitumen is applied uniformly over the surface at required rate per square yard.	(1) Distributor, 800-gallon, truck-mounted.	XII	Size of distributor selected depends on volume of material to be handled. (See fig. 39.)
	(2) Distributor, 1250-gallon, trailer-mounted (truck as prime mover).	XII	
	(3) Tank, 1500-gallon, trailer-mounted, with trailer-mounted pump and distributor (truck as prime mover).	XII	
c. *Spreading aggregate.* Aggregate is spread in thin uniform layers over the treated surface.	(1) Trucks, dump (2) Trucks, cargo. (3) Spreader, aggregate, towed (truck as prime mover). (4) Drag, brush (truck as prime mover).	VI	Dump trucks or cargo trucks with expedient beds used to haul and dump aggregate into a spreader box (fig. 40) for uniform distribution over surface. Aggregate may also be spread from trucks by hand or by controlling the tailgate. Brush drag is used to smooth the surface.
d. *Compaction.* Compaction consolidates bitumen and aggregate.	(1) Roller, road, gas-engine driven, two-axle, tandem, 5- to 8-ton.	XI	Equally effective. Tandem rollers (fig. 41) best for smoothing; rubber-tired rollers for kneading.
	(2) Roller, road, wheeled, rubber-tired, 13-tires (rubber-tired wheeled tractor or truck as prime mover).	XI	
19. BITUMINOUS PAVEMENT CONSTRUCTION. Compacted mixtures of bitumen and aggregate. There are three methods of construction. a. *Mixed-in-place pavements.* Constructed by mixing bituminous material with aggregate on the road, runway, or taxiway.			

Table I. *Construction operations and assignment of equipment. Contd.*

Work Item Construction Operation	Equipment	Reference to secs. of ch. 3	Application
(1) *Spreading the bitumen.* Prepared aggregate is bladed into parallel windrows of uniform size. Then the windrow is flattened and bitumen is applied in two or more applications until the required quantity has been added.	(1) (*a*) Grader, road, motorized. (*b*) Grader, road, towed (tractor as prime mover).	VII and II	Best machine for forming and flattening windrows. (See fig. 42.)
	(2) (*a*) Distributor, truck-mounted 800-gallon.	XII	Used to distribute bitumen over the flattened windrow.
	(*b*) Distributor, 1200-gallon, trailer-mounted (truck as prime mover).	XII	
	(*c*) Tank, 1500-gallon, trailer-mounted, with trailer-mounted pump and distributor (truck as prime mover).	XII	
(2) *Mixing.* (*a*) Blade-grader method.	(1) Grader, road, motorized. (2) Grader, road, towed (tractor as prime mover).	VII VII and II	Grader moves windrow from side to side by successive cuts. Best results are attained if several graders work one behind the other on each windrow. After complete mixing, material is left in a windrow.
(*b*) Rotary-tiller method.	(1) Mixer, rotary tiller, soil-stabilization.	VIII	Used to mix a flattened windrow.
(*c*) Travel-plant method.	(1) Asphalt and soil aggregate mixer, semitrailer-mounted, gasoline-engine-driven (supplemented with bucket loader and asphalt supply tanks).	XII	Used to pick up windrow of *dry* aggregate, add and mix the bitumen with aggregate, and replace windrow. (See fig. 43.) Used for cold-laid mixes only.
(3) *Spreading.*	(1) Grader, road, motorized. (2) Grader, road, towed (tractor as prime mover).	VII	Used to spread the windrow of mixed bitumen and aggregate to correct thickness.

(4) *Compaction.*	(1) Roller, road, wheeled, rubber-tired, 13-tires (rubber-tired wheeled tractor or truck as prime mover).	XI	Best unit for most of the compaction.
	(2) Roller, road, gas-engine-driven, two-axle, tandem, 5- to 8-ton.	XI	Best unit for initial compaction and finish rolling.
	(3) Roller, road, gas-engine-driven, 3-wheel, 10-ton.	XI	Used to complete compaction after initial rolling with tandem or rubber-tired rollers and after curing to prevent displacement.
b. Plant-mixed bituminous pavements.			
(1) *Mixing.*	Asphalt plant, 10-unit.	XII	Used for central plant mixing of the materials. (See fig. 44.) Used for cold-laid and hot-laid mixes.
(2) *Placing mixture.*	(1) Trucks, dump.	VI	
	(2) Spreading and finishing machine.	XII	Mixed material is transported by trucks. Cold-mixture is dumped into spreading and finishing machine, or spread by grader or by hand. Hot-mixture is dumped into spreading and finishing machine or spread by hand.
	(3) (*a*) Grader, road, motorized. (*b*) Grader, road, towed (tractor as prime mover).	VII and II	
(3) *Compaction.* (*a*) Hot-laid	(1) Roller, road, gas-engine-driven, 3-wheel, 10-ton.	XI	Three-wheel roller used for initial compaction (break-down rolling) of hot-laid mixtures. Two-axle tandem roller used in final lengthwise, diagonal, and cross rolling.
(*b*) Cold-laid	(2) Roller, road, two-axle, tandem. See work item 19*a* (4).	XI	
c. Penetration macadam pavement.	(1) Truck, dump.	VI	Trucks dump coarse aggregate on base. Grader or

Table I. Construction operations and assignment of equipment. Contd.

Work Item / Construction Operation	Equipment	Reference to secs. of ch. 3	Application
(1) *Spreading and compacting coarse aggregate.*	(2) (*a*) Grader, road, motorized.	VII and II	dozer spreads it to loosely uniform depth, and roller dry-rolls it to a firm even surface true to cross section. The dozer is a poor substitute for the grader in this operation.
	(*b*) Grader, road, towed (tractor as prime mover).		
	(3) Dozer, tractor-mounted (including tiltdozer, angledozer, or bulldozer blades).	III and II	
	(4) Roller, road, gas-engine-driven, 3-wheel, 10-ton.	XI	
(2) *Spreading bitumen.*	(1) Distributor, 800-gallon, truck-mounted.	XII	Best units for applying bitumen.
	(2) Distributor, 1200-gallon, trailer-mounted (truck as prime mover).	XII	
	(3) Tank, 1500-gallon trailer-mounted, with trailer-mounted pump and distributor (truck as prime mover).		
(3) *Spreading fine aggregate.*	(1) Truck, dump, with spreader box.	VI	Fine aggregate is spread uniformly by spreader boxes, tailgate control, or hand.
	(2) Truck, dump.		
(4) *Compaction (finishing).*	See *a* (3) above.		
20. RIGID PAVEMENT CONSTRUCTION. Subgrade preparation, which must be completed just before pavement construction, includes fine grading, compacting by rolling, and sprinkling.			

a. *Batching.* Combining aggregates in desired weight and proportions.	(1) Batching plant, aggregate, three-compartment, 105-ton capacity.	XIII	Clamshell used to load aggregates into batching plant from stock piles or hauling units. The batching plant delivers properly proportioned batches of aggregate to dump trucks for hauling to construction site.
	(2) Truck, dump (with batch compartments).	VI	
	(3) Clamshell, truck- or crawler-mounted.	V	
b. *Mixing.*	(1) Paver, concrete, crawler-mounted.	XIII	Best unit for construction of road and runway pavements. (See fig. 45.) Concrete mixer can be used when concrete paver is not available. Operates most efficiently at a central plant with dump trucks hauling mixed concrete to paving site where it is dumped and spread by hand labor.
	(2) Mixer, concrete, trailer-mounted (truck as prime mover).		
c. *Placing and spreading.*	(1) Spreader, concrete.	XIII	Spreader is best piece of equipment for distributing concrete as it comes from the paver. (See fig. 45.)
d. *Finishing.*	(2) Truck, dump. Finisher, concrete.	VI	Finisher is best piece of equipment for consolidating concrete and striking off final finished surface. It can be replaced by laborers using hand tools and improvised equipment.

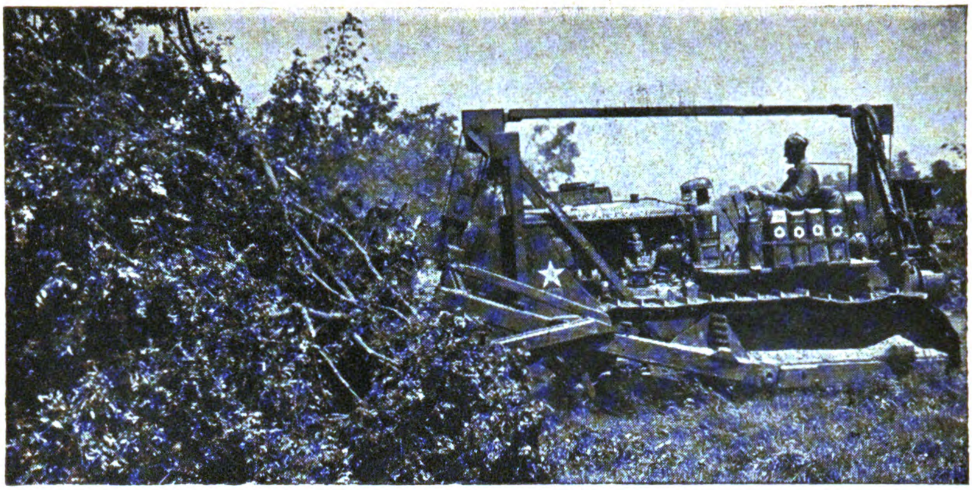


Figure 6. Tractor of 80 dbhp with angledozer windrowing small trees and brush.

Figure 7. Chain saw cutting fallen tree into short lengths.

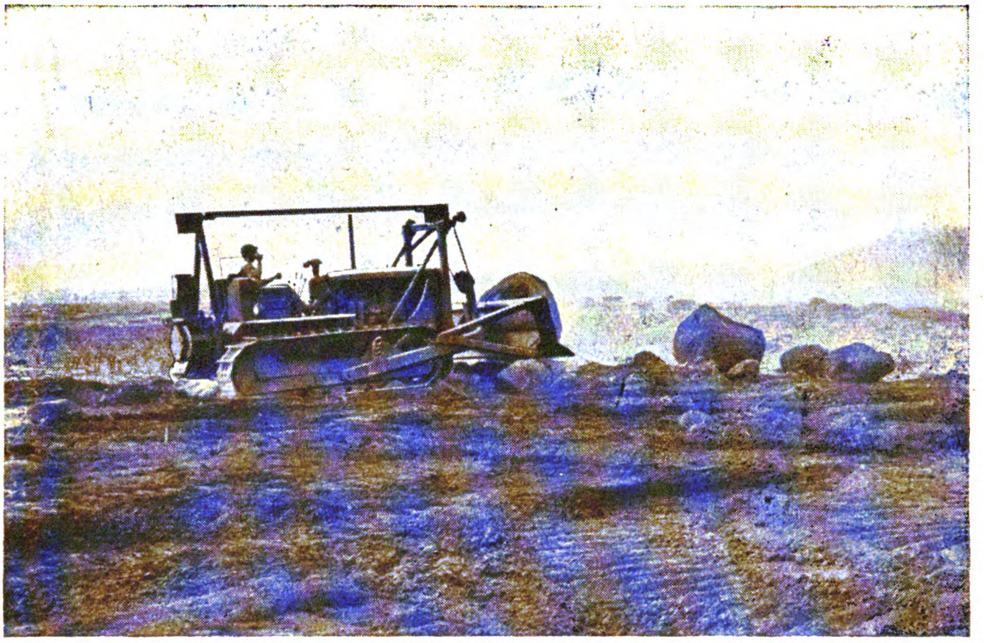


Figure 8. Dozer removing large boulders from landing strip.

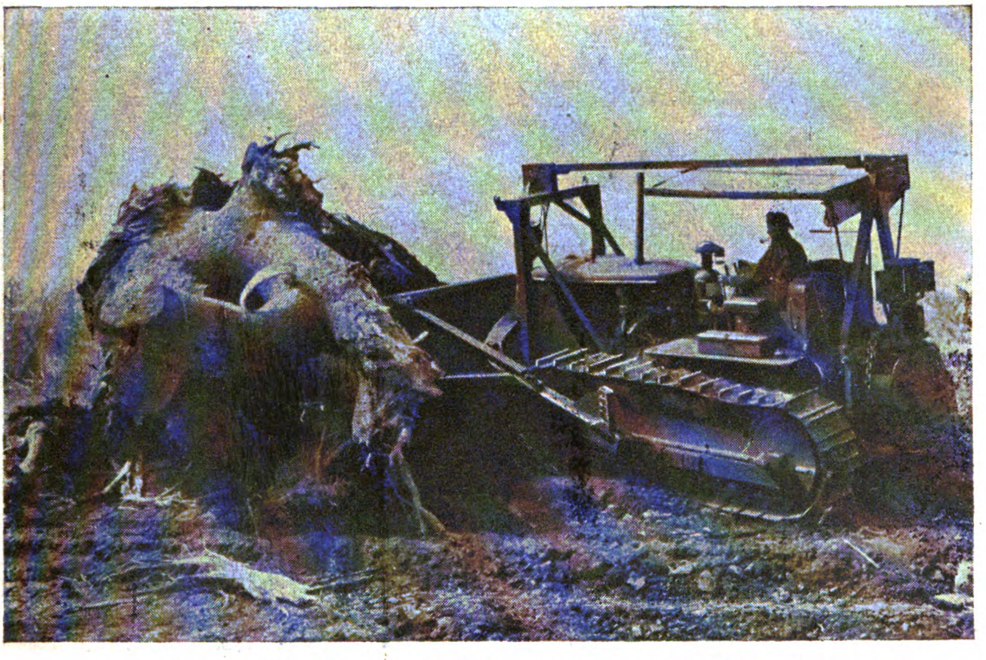


Figure 9. Dozer removing large stump from landing strip.

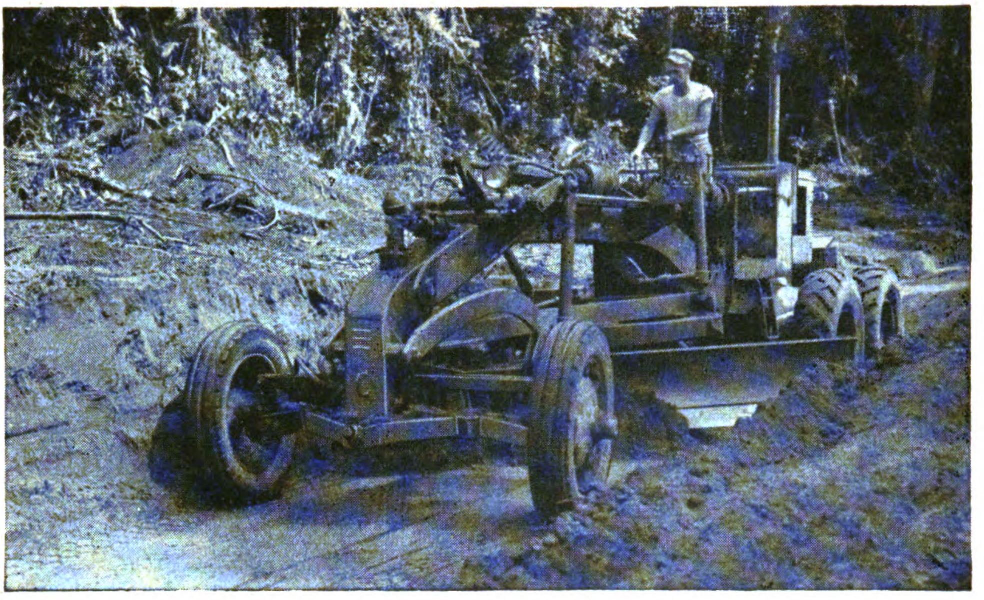


Figure 10. Motorized grader excavating a roadside ditch.

Figure 11. Angledozer excavating side ditch for pioneer road in heavy soil.

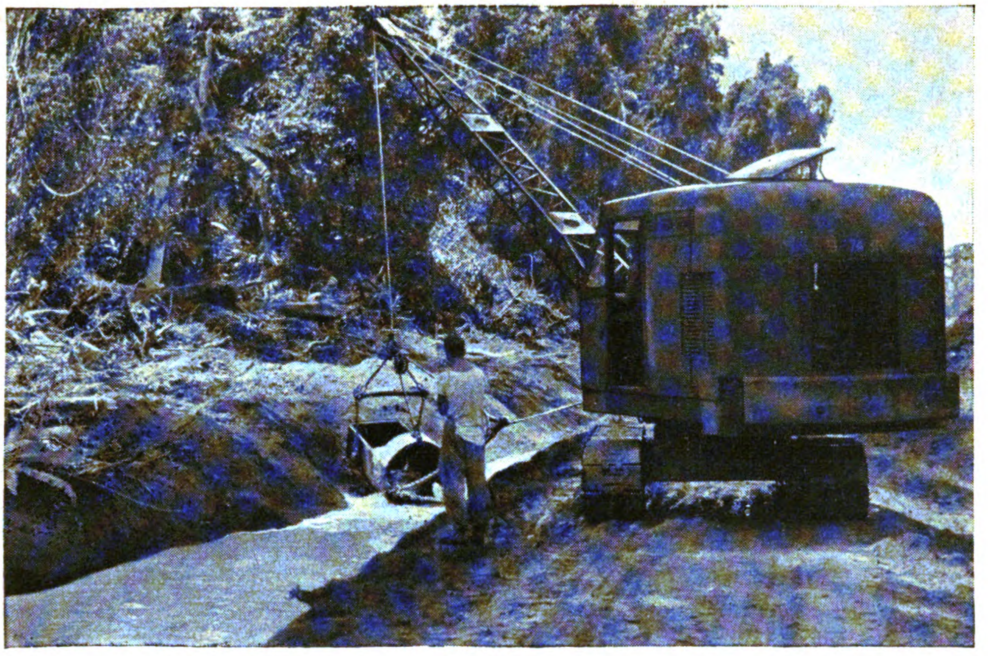


Figure 12. Dragline excavating large drainage ditch.

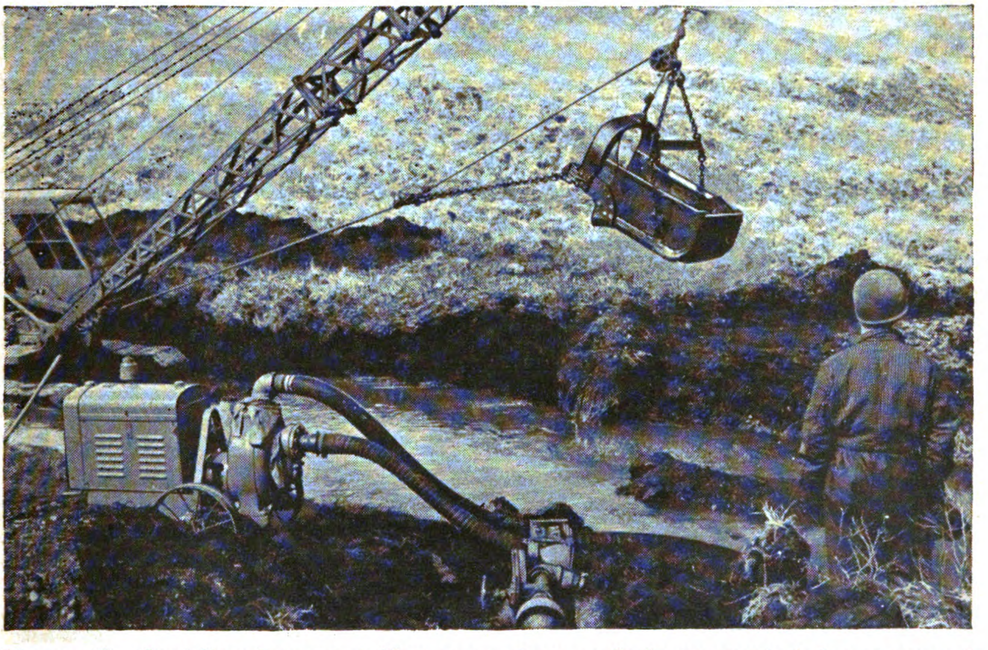


Figure 13. Centrifugal pump taking water from a drainage sump being excavated by a dragline.

Figure 14. Bulldozer backfilling against a completed log culvert under a pioneer-road embankment.

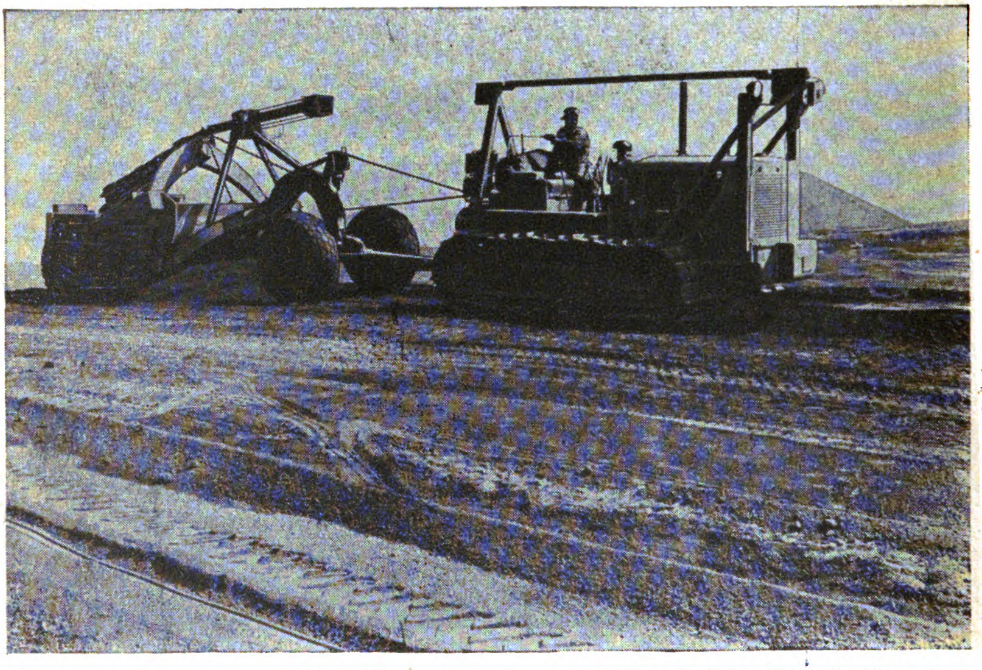


Figure 15. D7 tractor and 8-cubic-yard scraper excavating light soil for landing-strip embankment.

Figure 16. Angledozer excavating sidehill cut for pioneer road in light soil.

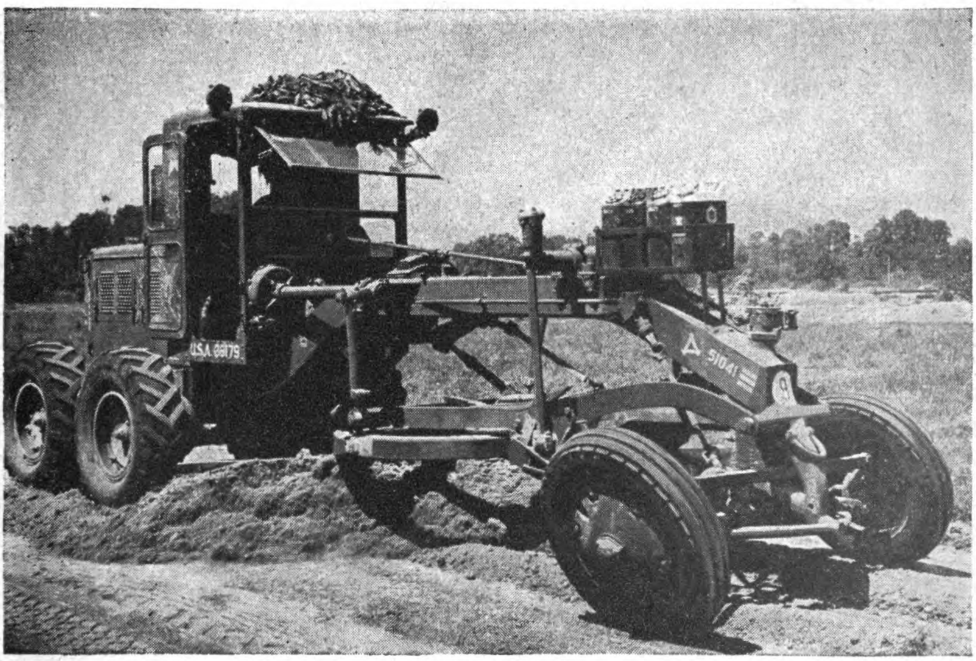


Figure 17. Motorized grader building road in medium soil.

Figure 18. Power shovel digging light soil and loading cargo trucks for long haul in landing-strip embankment construction. The cargo trucks are quickly unloaded by native labor.

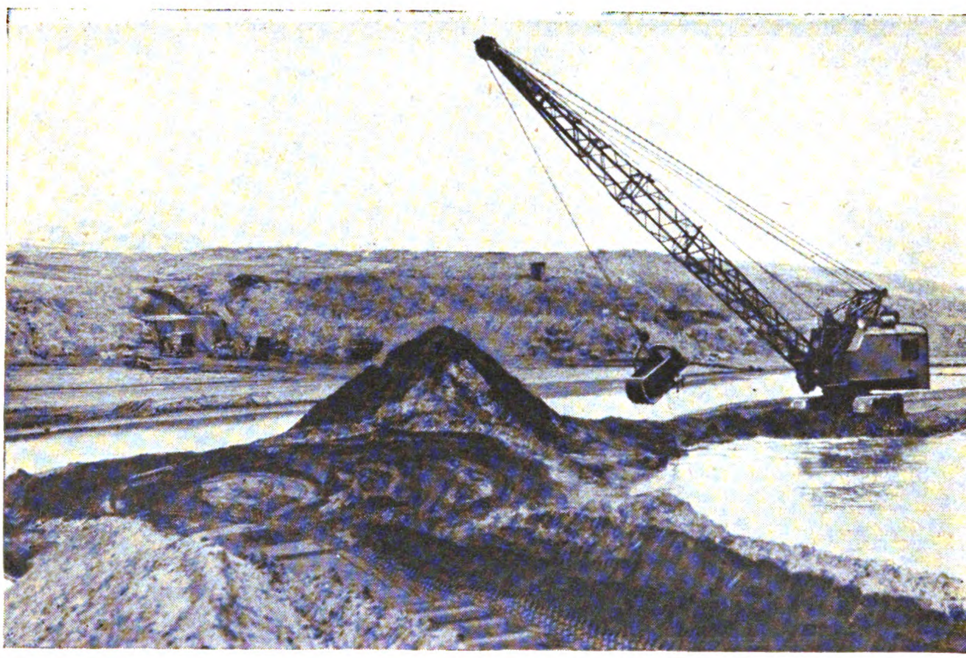


Figure 19. Fill material for taxiways and hard standings being excavated from below water level by 2-cubic-yard dragline. Material is hauled to fill by scrapers.

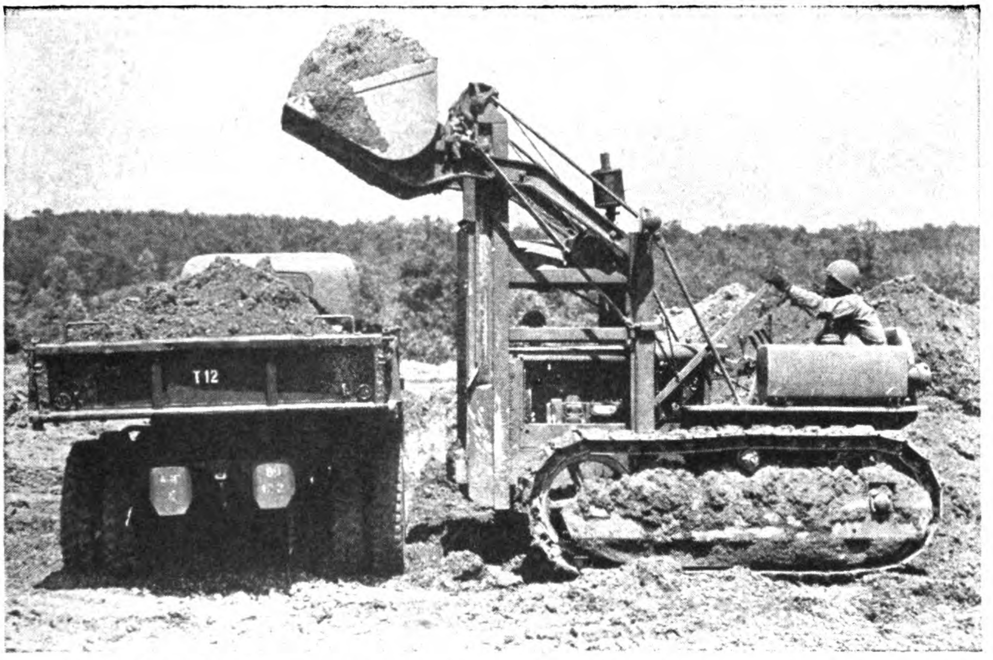


Figure 20. **Tractor-mounted 1-cubic-yard bucket loader loading truck with light soil from confined excavation.**

Figure 21. **Motorized 8-cubic-yard scraper with 80-dbhp pusher tractor loading heavy soil in landing-strip construction.**

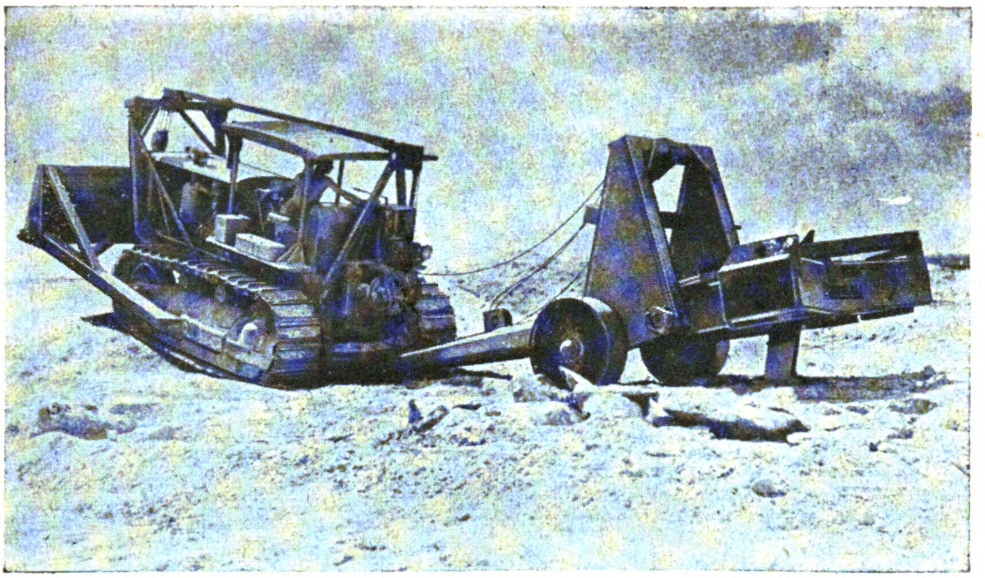


Figure 22. Rooter towed by 91-120 dbhp tractor loosening consolidated material before excavation.

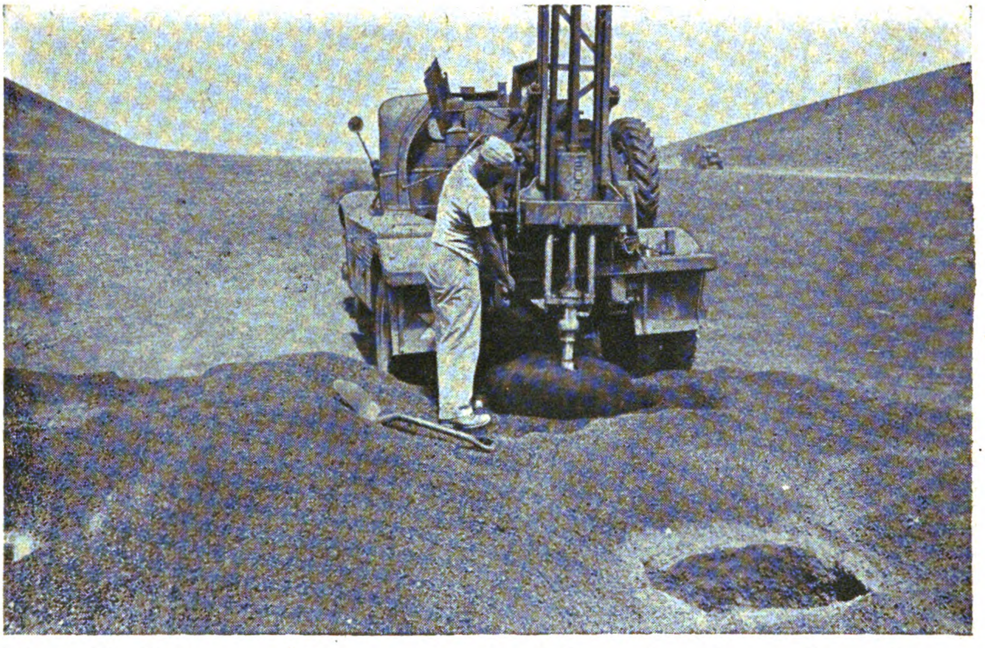


Figure 23. Earth auger digging exploration holes to determine quality and availability of material for landing-strip embankment.

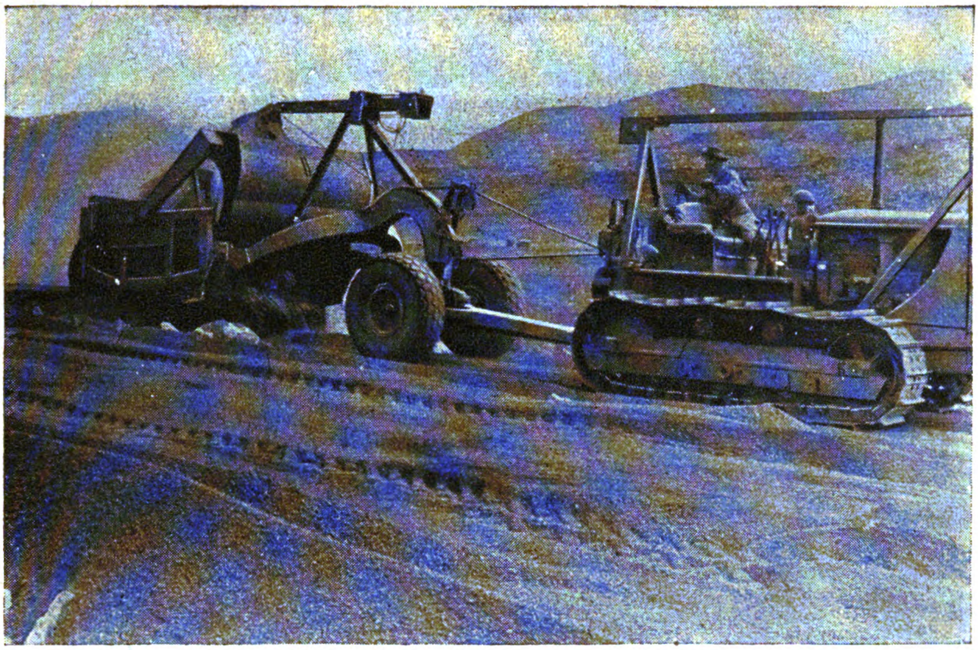


Figure 24. Eighty-dbhp tractor with 8-cubic-yard scraper spreading landing-strip embankment material in a 12-inch layer.

Figure 25. Dump truck using tailgate to control spread of gravel being dumped on road subgrade.

Figure 26. Motorized grader spreading piles of base-course material left by dump trucks.

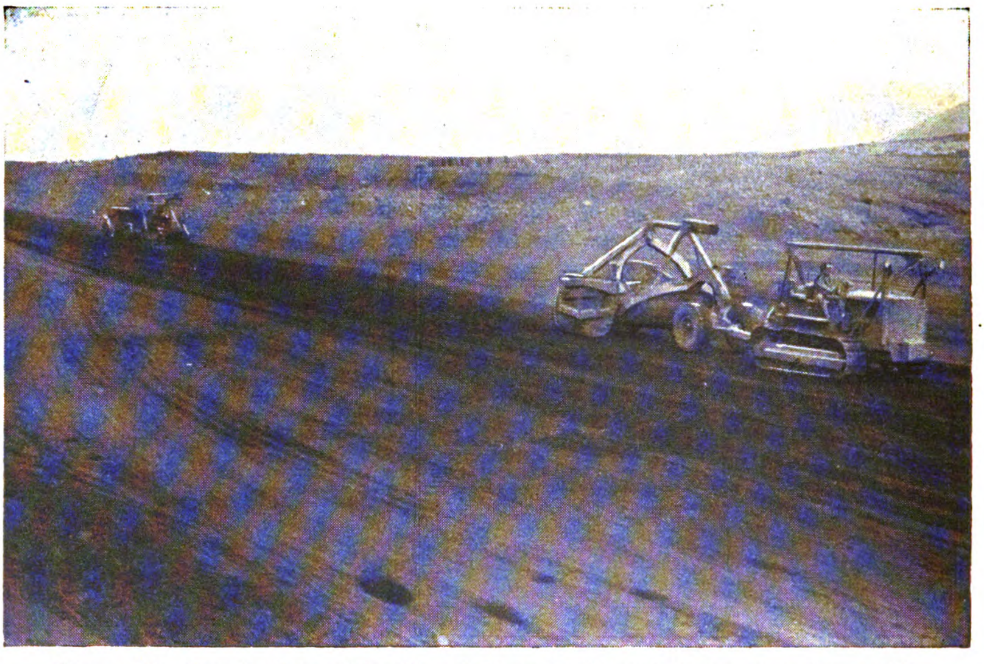


Figure 27. Compaction of landing-strip embankment by construction traffic.

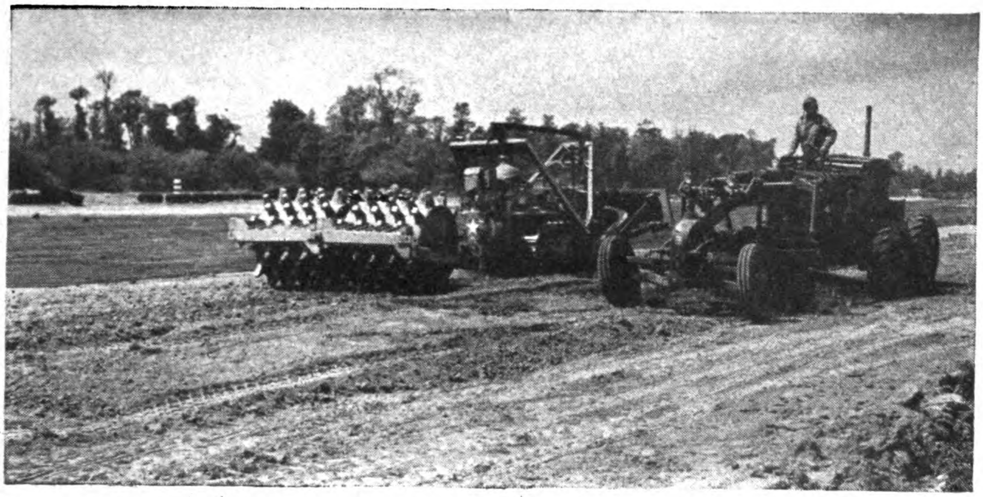


Figure 28. Sheepsfoot roller towed by 66- to 90-dbhp tractor compacts runway subgrade shaped by motorized grader.

Figure 29. Motorized graders loosening and leveling surface of a landing strip. Graders working in tandem develop maximum efficiency.

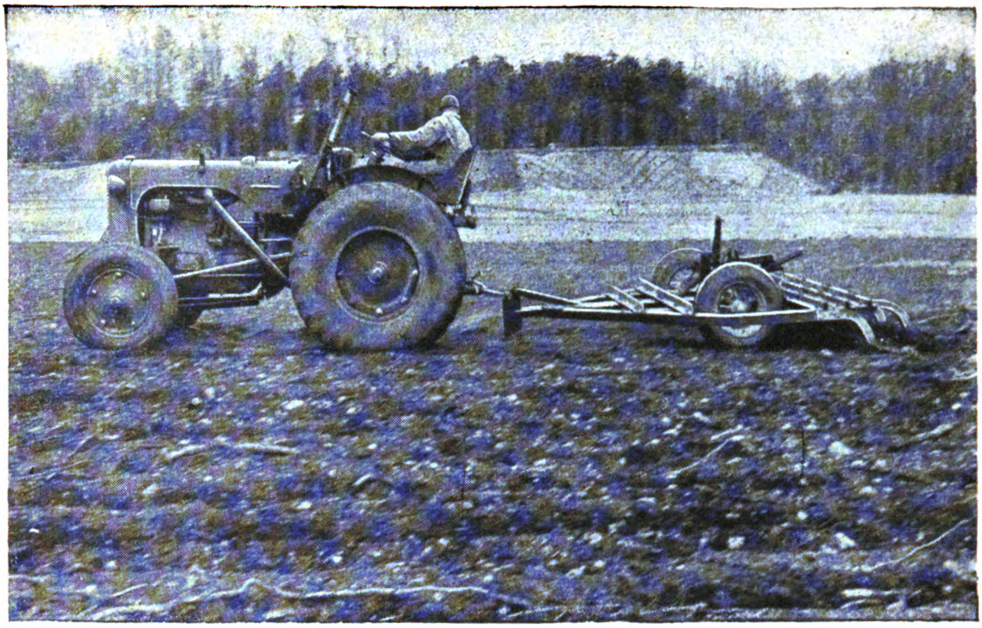


Figure 30. Chisel-tooth cultivator loosening heavy soil containing rocks and small roots.

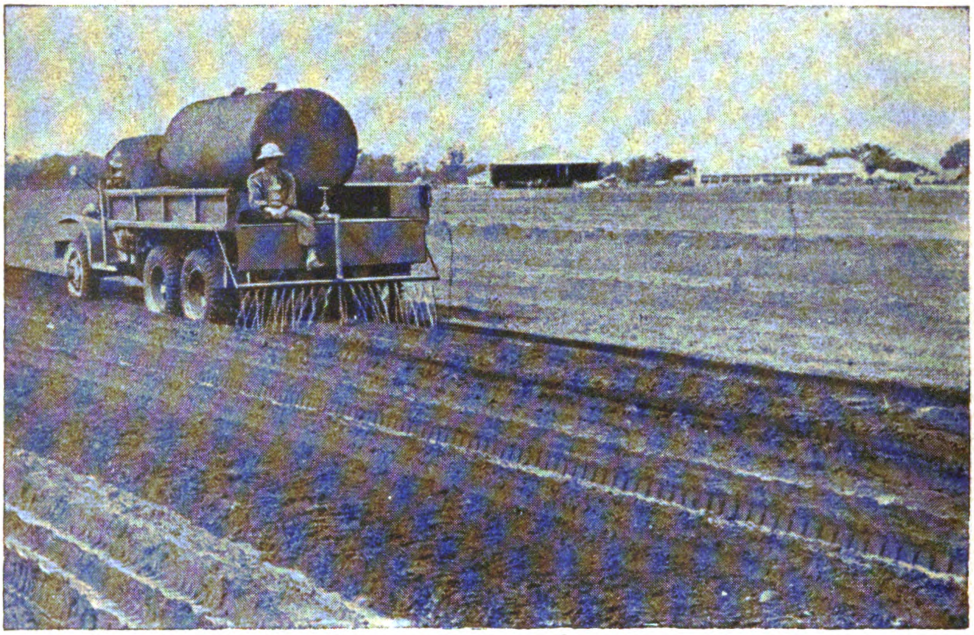


Figure 31. Skid-mounted 750-gallon tank placed on truck and equipped with spray bar for sprinkling base-course material.

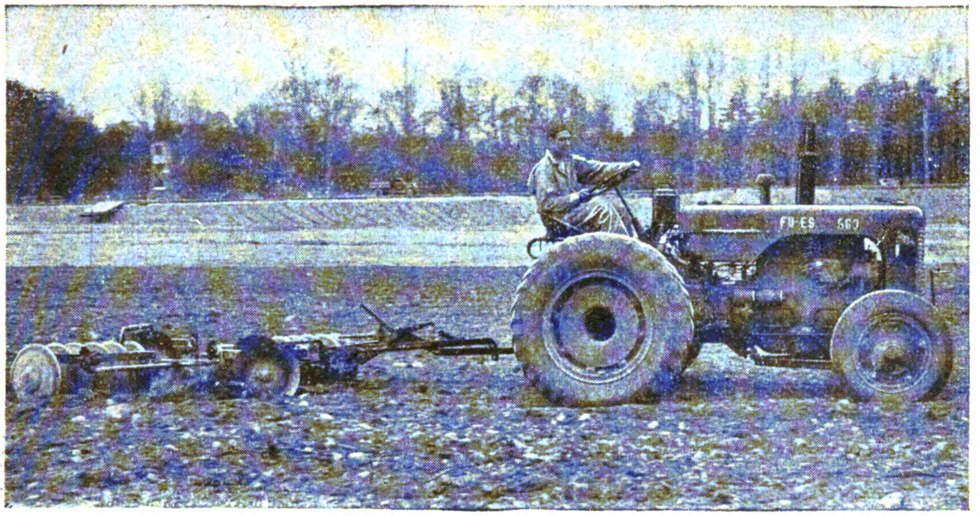


Figure 32. Tandem disc harrow pulverizing clods of heavy soil.

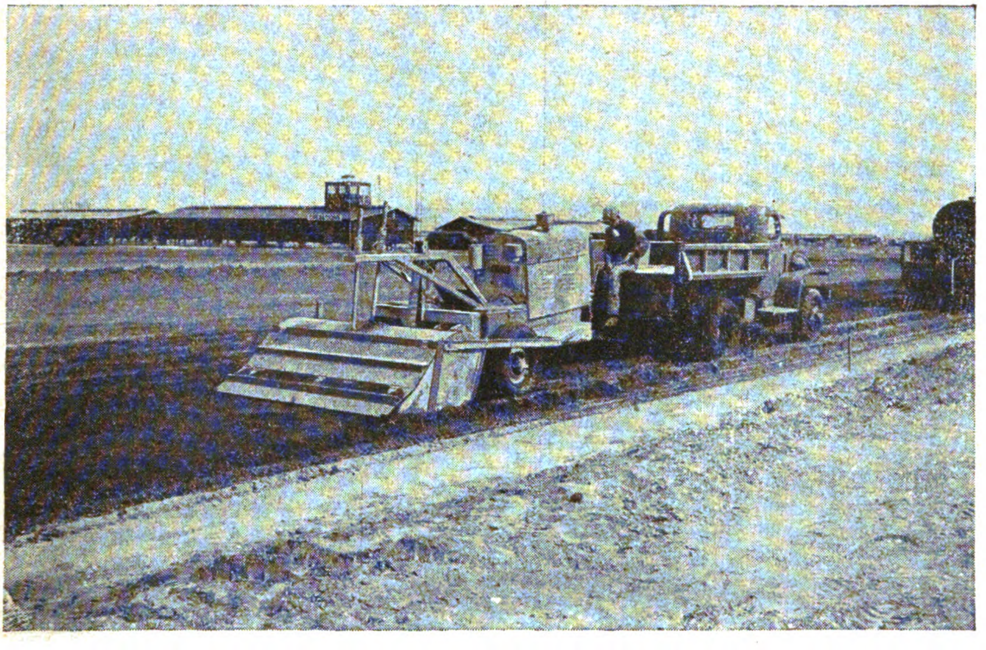


Figure 33. Rotary tiller mixing base-course material in landing-strip construction. Note truck-mounted sprinkler moving ahead of tiller.

Figure 34. Pneumatic paving breaker shattering and scaling rock in quarry operations.

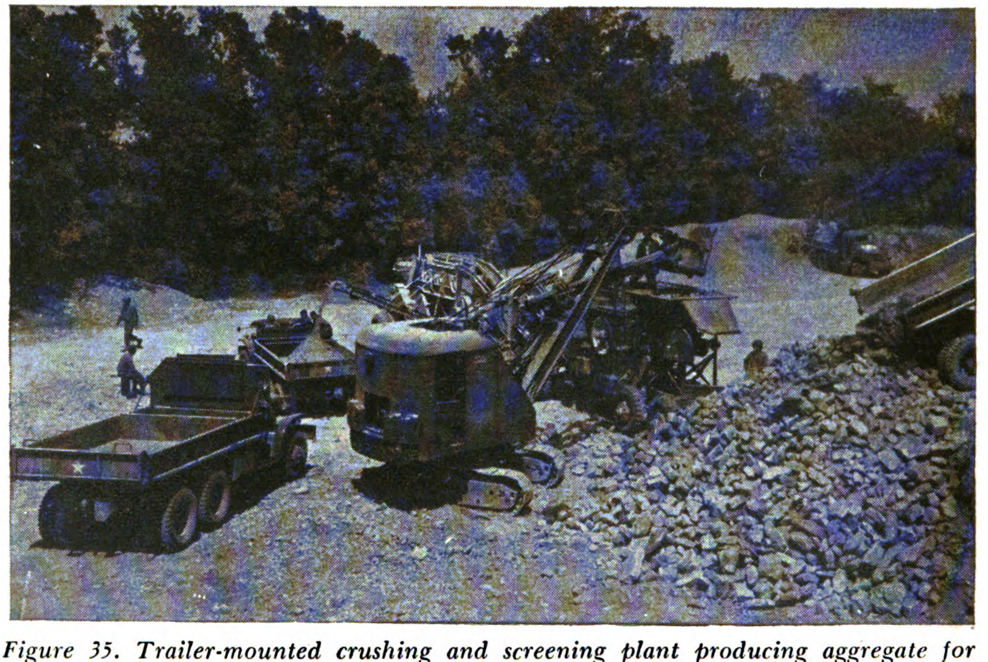


Figure 35. Trailer-mounted crushing and screening plant producing aggregate for road construction. Dump truck is delivering material from the quarry, power shovel is lifting rock to hopper of crusher, and one dump truck, with another waiting its turn, is receiving crushed rock.

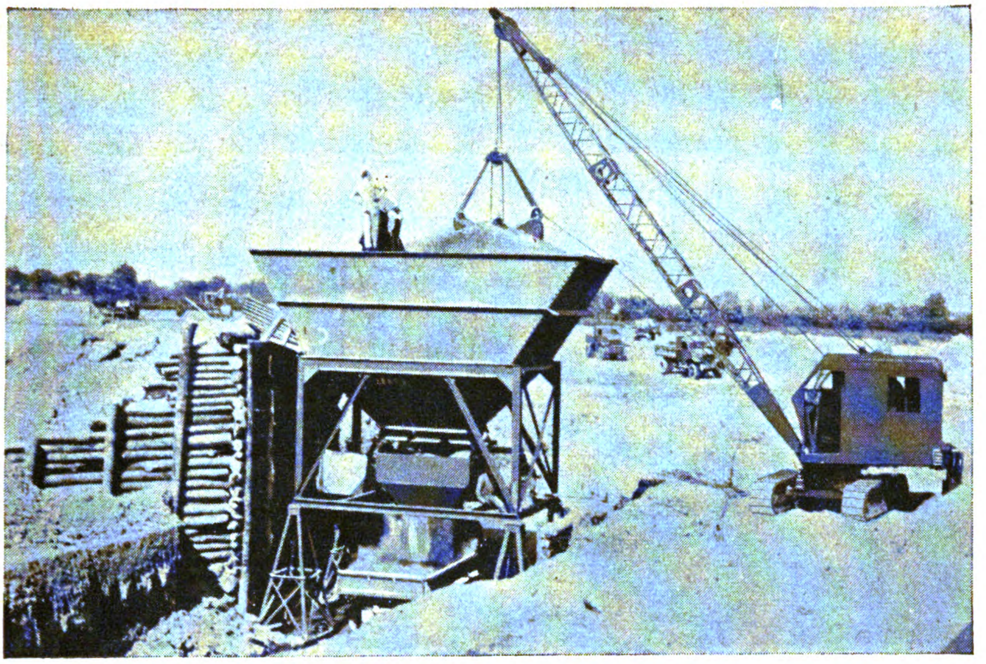


Figure 36. Clamshell loading aggregates from stock pile into batching plant. Dump truck is receiving a batch of aggregate from the plant.

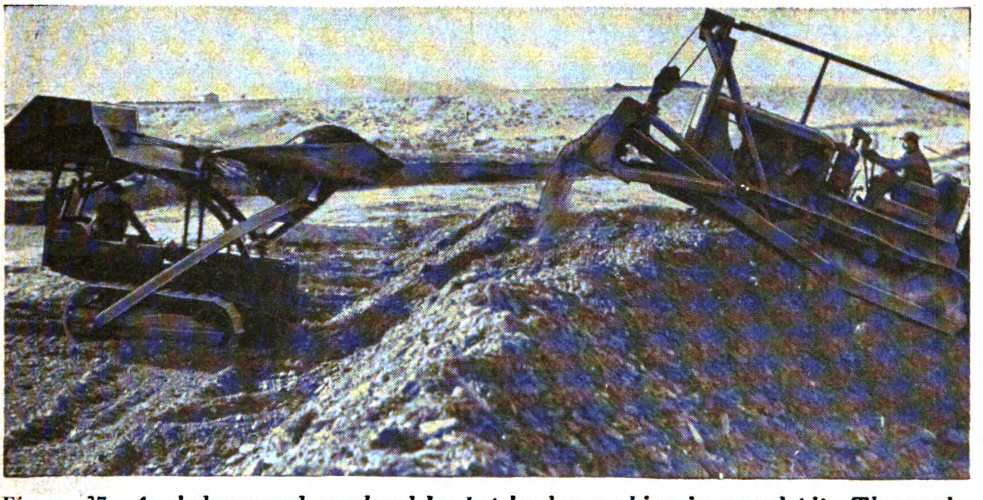


Figure 37. Angledozer and overhead bucket loader working in gravel pit. The angledozer is excavating and piling the gravel and the loader is loading dump trucks.

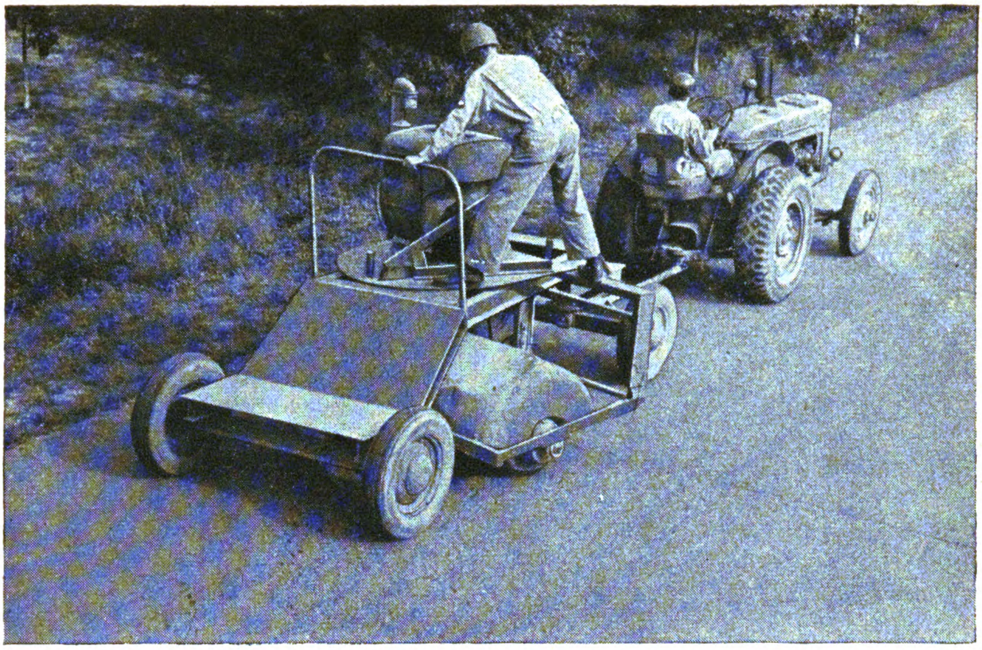


Figure 38. Rotary broom sweeping loose material from surface to be treated.

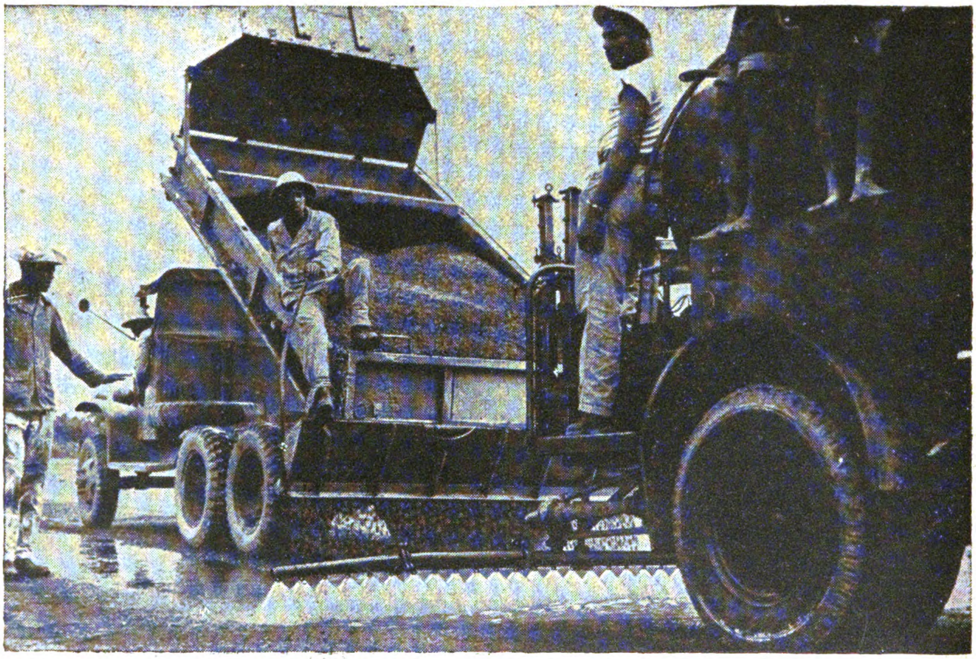


Figure 39. Trailer-mounted bituminous distributor spreading bitumen in surface treatment of a runway. Dump truck equipped with spreader is placing cover aggregate.

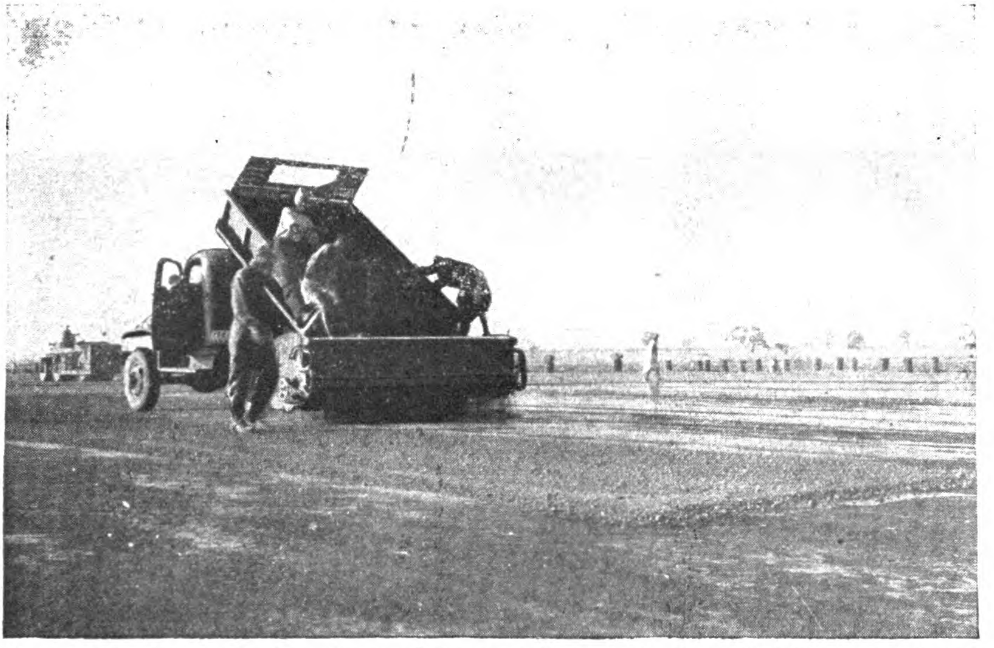


Figure 40. Aggregate spreader used to spread aggregate from $2\frac{1}{2}$-ton dump truck for bituminous surface treatment of runway.

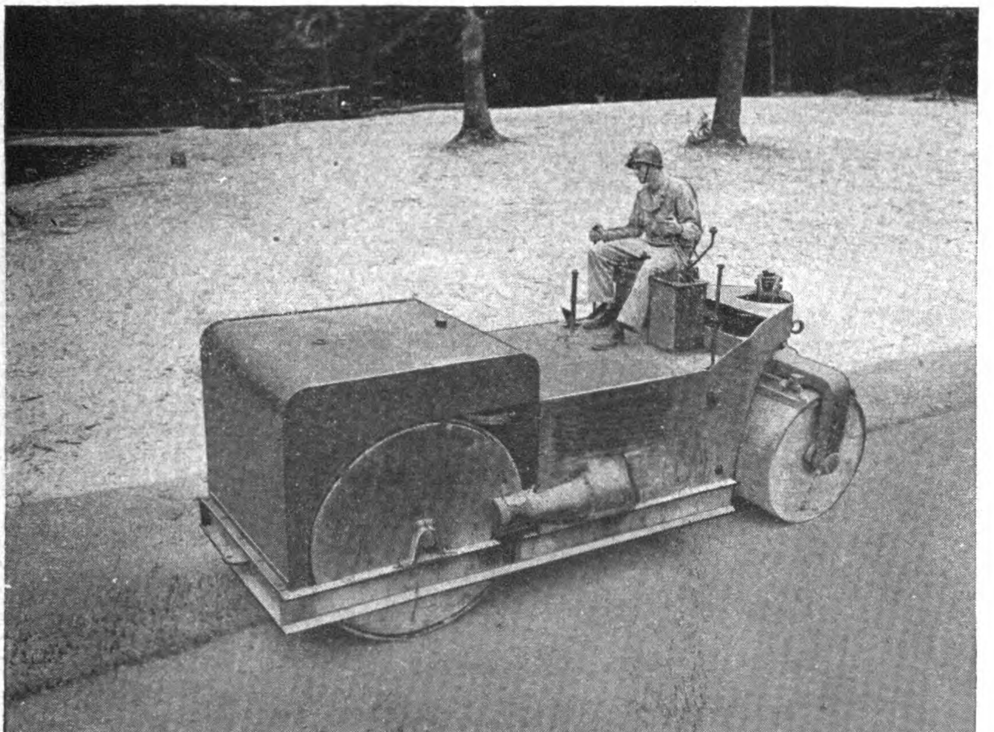


Figure 41. Roller compacting bitumen and aggregate.

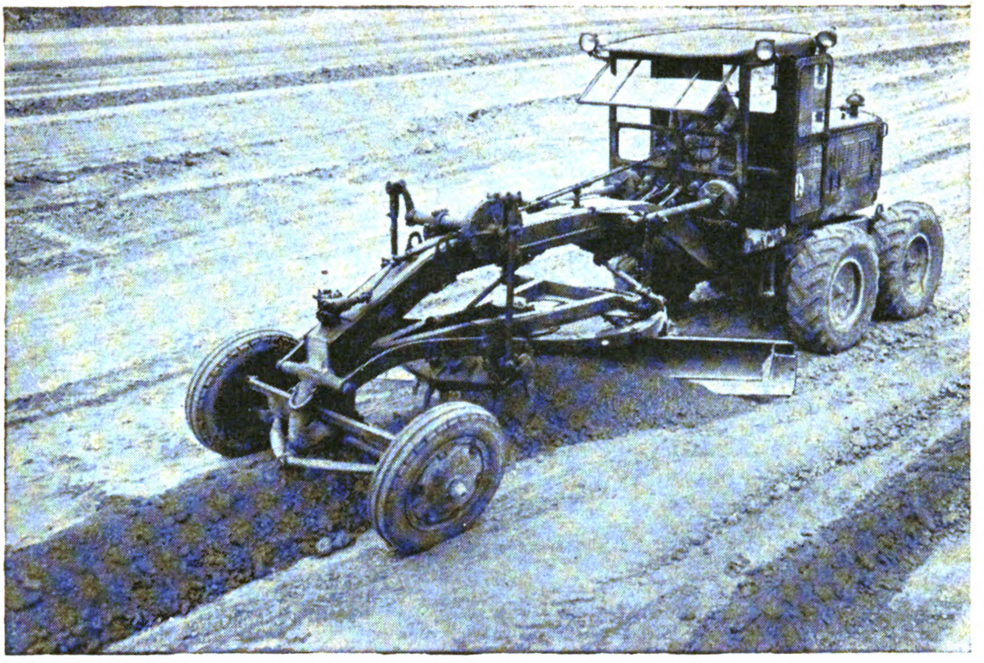


Figure 42. Blade grader working windrowed material.

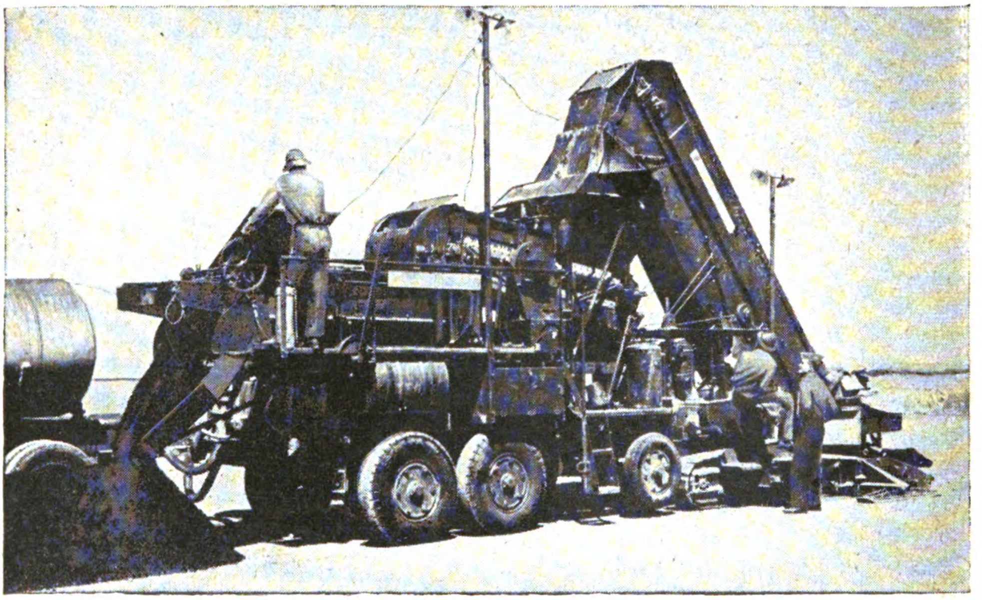


Figure 43. Traveling asphalt plant consisting of bucket loader and mixer.

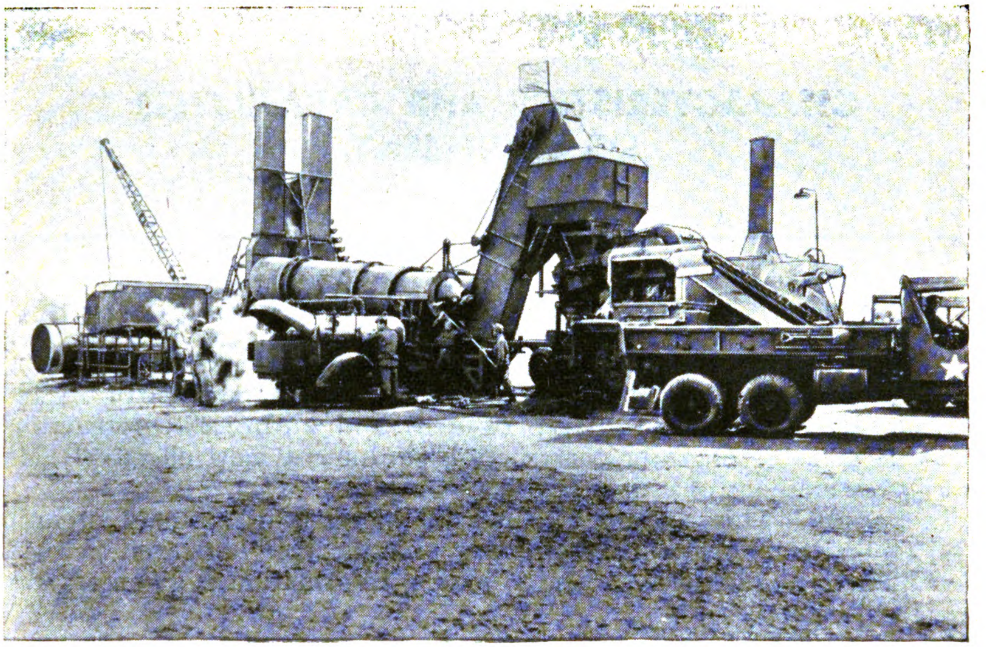


Figure 44. Asphalt and aggregate mixing plant in operation. This plant consists of 10 units and will produce from 80 to 150 tons of mixed bitumen and aggregate per hour.

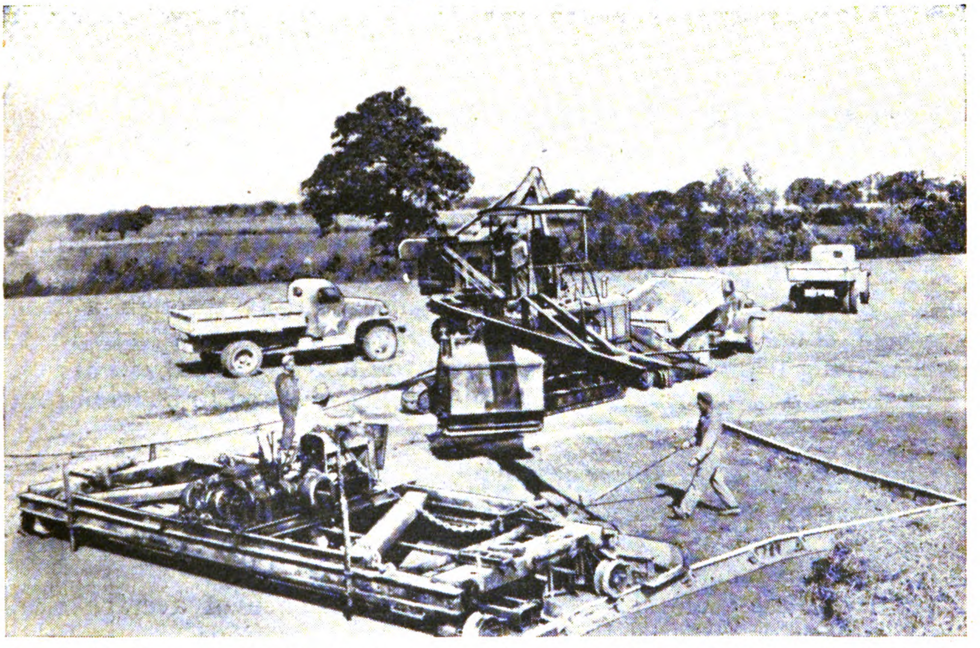


Figure 45. Concrete paving plant constructing taxiways for airdrome. Plant consists of 34E paver, 20-foot-wide form-riding concrete finisher, dump trucks delivering batched aggregate, and steel forms.

CHAPTER 3

CHARACTERISTICS AND CAPABILITIES OF EQUIPMENT

Section I. GENERAL

14. PURPOSE AND SCOPE. a. Purpose. The purpose of this chapter is to aid officers in charge of road and airdrome construction projects in using engineer construction equipment most effectively. It also gives methods of estimating work output.

b. Scope. This chapter discusses all pieces of equipment organic and immediately available to engineer units normally engaged in road and airdrome construction. The following information is given regarding equipment:

(1) Physical characteristics.
(2) Primary and secondary uses.
(3) Methods of estimating work output.
(4) Principles of management for maximum work output.

15. PHYSICAL CHARACTERISTICS. Information is given on dimensions, weights, and other characteristics useful in planning transportation and application and in estimating work output.

16. PRIMARY AND SECONDARY USES. a. Primary uses. These are the uses for which a piece of equipment is designed. Maximum work output is normally obtained.

b. Secondary uses. Some equipment can be put to uses for which it is not primarily designed. Normally it is substituted for other equipment and will perform with relatively low efficiency. For example under certain conditions, the dozer loading trucks through a trap, ramp, or chute (sec. II ch. 4), can replace the power shovel in an earth-moving team. The work output of the dozer (sec. III ch. 3), can be estimated and the number of hauling units adjusted to fit its output.

17. ESTIMATING WORK OUTPUT. a. Estimated work output of a piece of equipment is normally determined in two ways:

(1) By using a work output formula based on the cycle of operation and other factors which control production.

(2) By using tables based upon past experience of average work output under varying conditions for different operations.

Note. Work-output formulas and tables presented in this chapter should be used only as a guide and should be modified to meet demands of the situation.

b. To calculate output of earth-moving equipment, it is necessary to consider the volume changes in earth caused by handling. Understanding of the following terms is essential.

(1) *Swell.* Increase in volume of earth that results when it is dug from its natural position. The digging process loosens the earth and increases the percentage of air spaces between particles of dirt. Common earth has an average swell factor of 25 per cent. One cubic yard of common earth in its natural position will occupy 1.25 cubic yards when removed. (See fig. 46.)

(2) *Shrinkage.* Decrease in volume of earth when compacted. After compaction, common earth occupies approximately 10 per cent less space than it does in its natural undisturbed state.

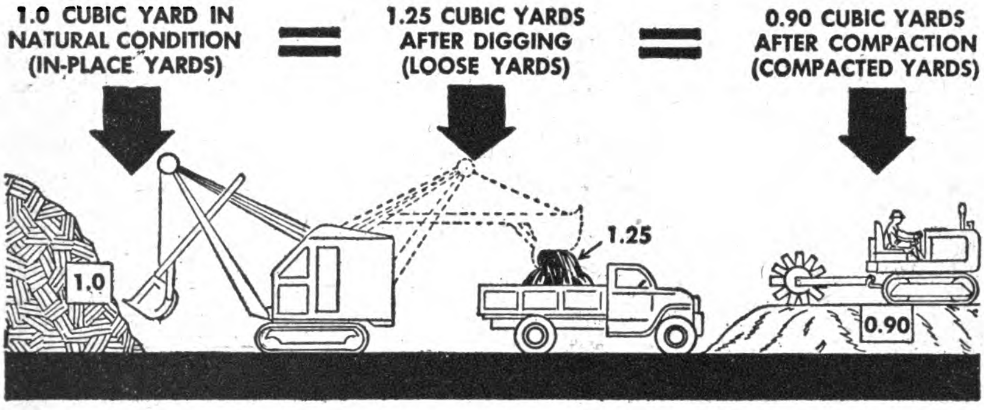


Figure 46. Volume changes in common earth caused by handling.

(3) *Loose yards.* Volume of earth after it has been removed from its natural location and swell has taken place.

(4) *In-place yards.* Volume of earth in its natural location before handling.

(5) *Compacted yards.* Volume of earth that has been properly compacted in an embankment or fill.

c. Field tests and formulas for computing the in-place and compacted volume and weight of any soil are given in appendix III of TM 5–255. Weight and volume of different materials are also given in TM 5–255. Soil conversion factors for sand, common earth, and clay are shown in table II.

d. Excavation and fill is calculated on the basis of loose yards, in-place yards, or compacted yards under the following conditions:

(1) Loose yards are used to express the carrying capacity of earth-moving equipment.

(2) In-place yards are converted to compacted yards to determine the volume of material in a fill that will be realized from a given amount of material in its natural location.

(3) In-place yards are converted to loose yards to determine the amount of earth-moving equipment required to handle the material.

(4) The output of equipment in loose yards must be converted to compacted yards to determine the final volume of fill.

18. PRINCIPLES OF MANAGEMENT. Principles of management for maximum work output include:

a. Handling equipment efficiently in specific types and conditions of material and terrain.

Table II. Soil conversion factors

Conversion factors for earth-volume change				
Soil type	Present soil condition	Converted to:		
		In place	Loose	Compacted
Sand	In place	1.00	1.11	0.95
	Loose	0.90	1.00	0.86
	Compacted	1.05	1.17	1.00
Common earth	In place	1.00	1.25	0.90
	Loose	0.80	1.00	0.72
	Compacted	1.11	1.39	1.00
Clay	In place	1.00	1.43	0.90
	Loose	0.70	1.00	0.63
	Compacted	1.11	1.59	1.00

Example: 1 cubic yard of *sand in place* equals 1.11 cubic yards *loose*.

b. Balancing the output of major pieces of equipment working in teams with labor and other pieces of equipment. Balancing requires enough supplemental and auxiliary equipment and labor to operate major pieces of equipment at their maximum output.

c. Employing special techniques in using equipment expediently.

d. Maintaining work output during extreme weather conditions.

Section II. TRACTORS

19. PHYSICAL CHARACTERISTICS. See table III for dimensions and weights of tractors.

20. USE OF TRACTORS. a. Purpose. Tractors are multipurpose machines designed to tow or push construction equipment. See table IV for drawbar pull and speed of tractors in all gears. Tractors are useful in virtually all road and runway construction operations.

b. Controlling factors. Use of tractors is controlled primarily by the type of material in which operations are performed.

(1) *Crawler-type tractors.* Crawler-type tractors operate best on material such as common earth and gravel. They can operate in muck or water to depths approximately to the top of the tracks. Full drawbar horsepower cannot be obtained on sand or smooth-rock surfaces because of track slippage.

(2) *Rubber-tired tractors.* Rubber-tired tractors operate best on gravel, common-earth, and smooth-rock surfaces. They can be used where crawler-type tractors would be harmful to the road or runway surface. Full drawbar horsepower (dbhp) cannot be obtained on sand or mud because of tire slippage. Operation in deep mud or muck is difficult or impossible.

Table III. Physical characteristics of tractors[1]

Equipment	Over-all dimensions			Weight[2] (pounds)
	Length (inches)	Width (inches)	Height (inches)	
Tractor, wheeled, rubber-tired, gasoline, 23–dbhp, Case S1.	129	50	73	3,300
Tractor, wheeled, rubber-tired, gasoline, 30–dbhp, Case D1.	110	64	66	4,000
Tractor, crawler, gasoline, 20–dbhp, Allis-Chalmers WM.	102	68	57	6,800
Tractor, crawler, gasoline, 35–dbhp, Caterpillar R4.	129	62	61	9,400
Tractor, crawler, Diesel, 35– to 40–dbhp, Caterpillar D4.	122	62	61	10,000
Tractor, crawler, Diesel, 35– to 40–dbhp, International TD–9.	114	76	67	9,850
Tractor, crawler, Diesel, 55– to 65–dbhp, Allis-Chalmers HD–7W.	125	70	86	13,600
Tractor, crawler, Diesel, 55– to 65–dbhp, Caterpillar D6.	150	81	73	16,300
Tractor, crawler, Diesel, 70– to 90–dbhp, Caterpillar D7.	163	98	80	23,700
Tractor, crawler, Diesel, 110– to 140–dbhp, Caterpillar D8.	183	104	90	34,200
Tractor, crawler, gasoline, 15–dbhp, Clark-Air, CA–1.	95	40	62	3,350

[1] Dimensions are maximum for tractors in each horsepower class.
[2] Without attachments.

Table IV. Speed and drawbar pull of various crawler-type tractors in different gears

Manufacturer		Allis-Chalmers			Caterpillar					International Harvester			Clark	Case	
Size		HD–14	HD–10	HD–7	D8	D7	D6	D4	R4	TD–18	TD–14	TD–9	CA–1	DI	SI
DBHP		108	79	55–65	110–140	70–90	55–65	35–40	35	71	54	35–40	15	30	23
Maximum drawbar pull and travel speed at rated engine speed															
1st gear	lb	24,600	18,430	12,171	26,208	21,351	14,300	7,852	7,211	18,973	13,500	9,014	4,000	2,640	2,090
	mph	1.72	1.69	1.84	1.6	1.4	1.4	1.7	1.7	1.50	1.50	1.5	1.48	2.24	1.95
2d gear	lb	19,250	14,800	8,570	19,537	13,454	9,100	5,811	5,186	13,357	9,750	6,637	4,000	2,640	2,090
	mph	2.18	2.06	2.55	2.2	2.2	2.3	2.4	2.4	2.00	2.10	2.2	2.25	4.29	2.77
3rd gear	lb	14,900	11,100	6,167	15,973	9,090	6,200	4,541	4,105	10,561	8,000	4,368	2,500	2,290	2,090
	mph	2.76	2.68	3.45	2.6	3.2	3.2	3.0	3.0	2.50	2.50	3.2	3.71	5.91	3.81
4th gear	lb	11,400	7,500	3,311	13,707	5,994	4,000	3,471	3,147	7,827	5,750	3,551	1,200	1,140	1,020
	mph	3.50	3.78	5.82	3.0	4.6	4.4	3.7	3.7	3.30	3.40	3.9	5.45	11.93	7.76
5th gear	lb	8,700	5,850	------	11,266	4,550	2,650	2,230	2,045	5,157	3,750	2,304	-----	-----	-----
	mph	4.36	4.62	------	3.6	6.0	5.8	5.4	5.4	4.60	4.80	5.3	-----	-----	-----
6th gear	lb	4,500	4,100	------	7,995	------	------	-----	-----	3,833	2,350	-----	-----	-----	-----
	mph	7.00	6.03	------	4.9	------	------	-----	-----	5.70	5.80	-----	-----	-----	-----

21. USE OF TRACTORS IN DEEP WATER. Tractors can operate in deep water for short periods of time if *properly waterproofed.* See table V for depths at which waterproofed tractors can operate.

Table V. Operating depths for waterproofed tractors.

Tractor	Operating depth (inches)
D8	70
D7	70
D6	60
D4	50
R4	50

Section III. DOZERS

22. PHYSICAL CHARACTERISTICS. See table VI for data on dimensions and weights of dozers.

23. USE OF DOZERS. a. Purpose. Dozers are a multipurpose machine capable of digging, pushing, dumping, and spreading. They are used primarily for short-haul excavation and as an auxiliary to other earth-moving equipment.

b. Controlling factors. Use of dozers is controlled by type and condition of material and length of haul.

(1) Dozers are most effective in soils which tend to remain in front of the bowl during travel. This includes most materials except loose granular material and shattered rock. Cemented materials require supplemental use of explosives or tractor-drawn rooters. Dozers cannot operate in muck higher than the top of tractor tracks.

(2) Dozers are most efficient at their loading distance of approximately 25 feet but will operate satisfactorily on hauls up to 300 feet. Tractor-drawn scrapers and power shovels with dump trucks are more efficient than dozers on hauls over 300 feet.

24. ESTIMATING WORK OUTPUT. a. Work output formula for earth moving. In excavation, stripping, and backfilling, the formula shown below is used to estimate work output in cubic yards per hour. Before using this formula, careful study should be given to paragraph 25a, and allowance made for the efficiency of each type dozer and the class of work to be performed.

$$\text{OUTPUT} = \frac{Q \times f \times 60 \times E}{Cm}$$ (in cubic yards, either *in-place* or *compacted* depending on conversion factor f)

Where, Q = bowl capacity in *loose* cubic yards.
f = soil conversion factor.
60 = minutes per hour.
E = the dozer efficiency factor.
Cm = total cycle time in minutes.

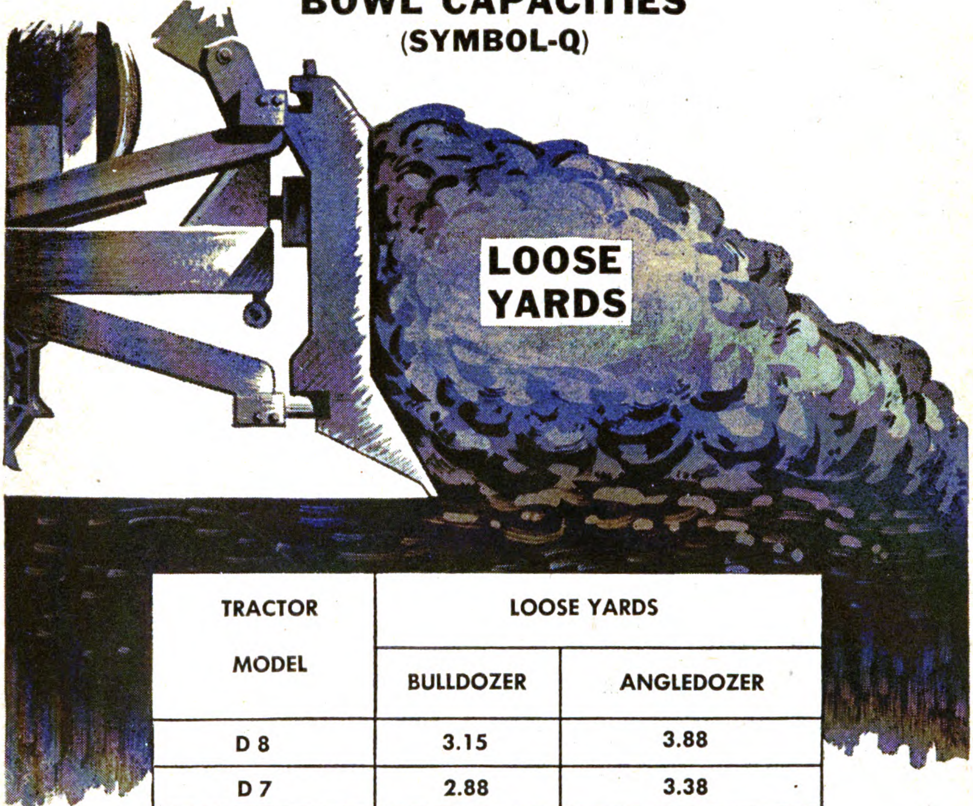
Table VI. Physical characteristics of dozers

Tractor	Dozer	Over-all dimensions			Weight (pounds) (blade, A-frame, and front PCU[2])	Weight (pounds) (blade, A-frame, and rear PCU)
		Mounted length (inches)	Mounted width (inches)	Mounted height (inches) (including A-frame)		
Caterpillar D8, 91–140 dbhp[1]	Bulldozer, tilting, model A8.	228	139	116	6, 280	7, 055
Caterpillar D8, 91–140 dbhp.	Angledozer, model CK8.	Straight 247 Angled 30° 273	Straight 163 Angled 30° 143	116	6, 660	7, 435
Caterpillar D8, 91–140 dbhp.	Bulldozer, rigid, model K8.	224	134	114	5, 610	6, 385
Caterpillar D7, 61–90 dbhp.	Bulldozer, tilting, model A7.	196	130	106	5, 300	6, 125
Caterpillar D7, 61–90 dbhp.	Angledozer, model WCK7.	Straight 207 Angled 30° 246	Straight 163 Angled 30° 139	113	6, 090	6, 945
Caterpillar D7, 61–90 dbhp.	Bulldozer, rigid, model XD7.	195	122	112	5, 100	5, 925
Caterpillar D6, 46–60 dbhp.	Bulldozer, tilting, model A6.	181	101	112	4, 230	5, 155
Caterpillar D6, 46–60 dbhp.	Angledozer, model SK6.	Straight 186 Angled 30° 216	Straight 133 Angled 30° 115	106	4, 930	5, 855
Caterpillar D6, 46–60 dbhp.	Bulldozer, rigid, model WK6.	185	122	112	3, 920	4, 855
Caterpillar D4, 36–45 dbhp.	Bulldozer, tilting, model 1A4.	162	84	99	3, 000	3, 865
Caterpillar D4, 36–45 dbhp.	Angledozer, model C4.	Straight 164½ Angled 30° 191	Straight 117 Angled 30° 101½	99	3, 780	4, 665
Caterpillar D4, 36–45 dbhp.	Bulldozer, rigid, model WE4.	155½	94	99	2, 930	3, 815

[1] Drawbar horsepower.
[2] Power control unit.

(1) *Bowl capacity* (*Q*). The bowl capacity of a dozer is the amount of loose earth it will push on level ground. Attention is called to figure 47 and table VII in which angledozers are shown to be capable of moving more material than can bulldozers. This is true only in uncompacted material in which angledozers can carry a full bowl of material. Bowl capacities must, therefore, be corrected for types of material and class of work to be accomplished.

BOWL CAPACITIES
(SYMBOL-Q)



TRACTOR MODEL	LOOSE YARDS	
	BULLDOZER	ANGLEDOZER
D 8	3.15	3.88
D 7	2.88	3.38
D 6	1.88	2.63
D 4	1.63	2.38

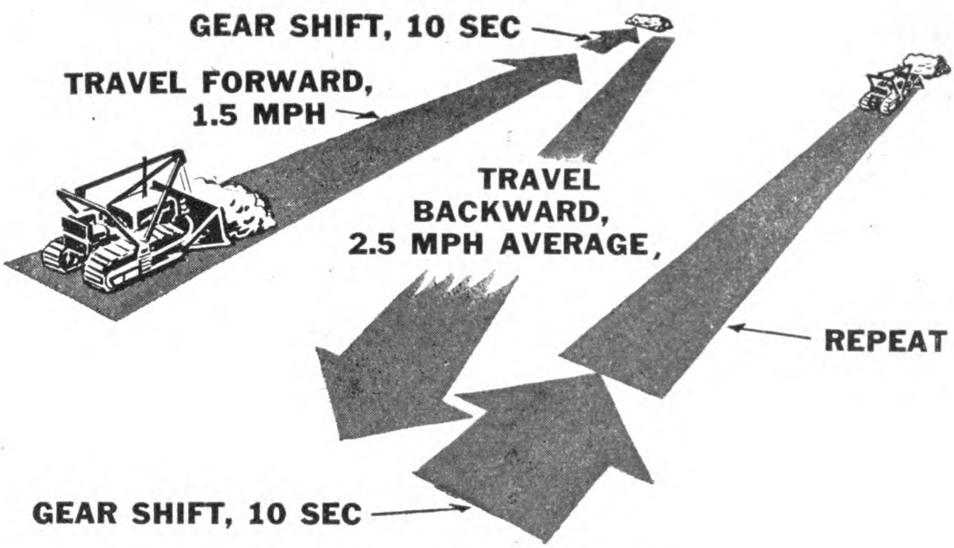
Figure 47. Bowl capacity of dozers.

(2) *Conversion factor* (*f*). The *loose* yards carried by the dozer can be converted to *in-place* yards or *compacted* yards by the proper conversion factor. See table II and paragraph 17.

(3) *Dozer efficiency factor* (*E*). The dozer efficiency factor takes into account the fact that a full 60-minute work hour is rarely obtained. Efficiency varies depending on supervision, operators, maintenance requirements, and site conditions. Experience shows that the average value of 80 per cent used in the example in figure 48 is normal, but it must be checked on each job by observation and experience.

(4) *Cycle time* (*Cm*). Total cycle time in minutes is made up of fixed time elements and variable time elements as follows:

(*a*) *Fixed time elements.* Gear shifting is the only fixed time ele-



EXAMPLE PROBLEM

GIVEN: D7 TRACTOR WITH ANGLEDOZER (BOWL CAPACITY (Q)=3.38 CU YD).

AVERAGE HAUL DISTANCE ONE WAY = 100 FT

COMMON EARTH

EFFICIENCY FACTOR (E)= 80%

SOIL CONVERSION FACTOR (F)(LOOSE TO IN-PLACE)= 0.80 (SEE TABLE)

DETERMINE: IN-PLACE CUBIC YARDS MOVED PER HOUR

STEP 1 ⟹ DETERMINE FIXED TIME

TWO GEAR SHIFTS @ 10 SEC PER SHIFT = 20 SEC = 0.33 MIN

STEP 2 ⟹ DETERMINE VARIABLE TIME

TRAVEL FORWARD 100 FT @ 1.5 MPH

$$\frac{100 \times 60}{1.5 \times 5280} = 0.76 \text{ MIN}$$

TRAVEL BACKWARD 100 FT @ 2.5 MPH

$$\frac{100 \times 60}{2.5 \times 5280} = 0.46 \text{ MIN}$$

STEP 3 ⟹ ADD FIXED AND VARIABLE TIME

TOTAL CYCLE TIME (Cm) = 0.33 + 0.76 + 0.46 = 1.55 MIN

STEP 4 ⟹ SUBSTITUTE IN WORK-OUTPUT FORMULA

OUTPUT:

$$\frac{\overset{(Q)}{3.38} \times \overset{(F)}{0.80} \times 60 \times \overset{(E)}{0.80}}{\underset{(Cm)}{1.55}} = 83\tfrac{1}{2} \text{ CU YD PER HR}$$

Figure 48. Example problem showing method of calculating dozer output.

ment and is independent of haul distance. It varies slightly with type of machine and skill of operator, but 10 seconds is a fair average value.

(*b*) *Variable time elements.* The time required for digging, pushing, and dumping material can be estimated on the basis of travel speed in different gears and the haul distance traveled in each gear. For speeds of different tractor models, see table IV.

b. Tables of typical work output. Tables VII, VIII, and IX give typical output of angledozers and bulldozers on specific construction operations. These yardages can be obtained only when all conditions are favorable. They should be used as a guide for estimating dozer performance, not as a table of output to be expected on every job.

Table VII. Typical dozer output on short haul excavation

Haul (one-way)	50 feet		100 feet		150 feet		200 feet	
Tractor	Bulldozer	Angledozer	Bulldozer	Angledozer	Bulldozer	Angledozer	Bulldozer	Angledozer
In-place yards per hour (average return speed 2.5 mph)								
D8	166	206	100	125	71	88	55	68
D7	153	180	93	108	66	77	51	60
D6	100	140	60	84	42	60	33	46
D4	81	128	52	76	37	54	28	42
In-place yards per hour (average return speed 5.0 mph)								
D8	187	233	116	143	83	103	65	81
D7	173	202	106	125	77	90	60	71
D6	113	158	69	97	50	70	39	55
D4	98	143	60	88	43	63	34	50

Conditions:
1. Level terrain.
2. Workable soil (2,700 to 3,000 pounds per cubic yard *in-place*).
3. 100 per cent efficiency. Apply proper efficiency factor (average E = .80) to obtain estimated output from values given in table.

Table VIII. Angledozer output (in-place yards per hour) on sidehill cut

Kind of soil	Tractor model		
	D6	D7	D8
Light, loose soil (loam)	95	120	170
Heavy soil	70	90	125
Shale	50	70	100
Boulders or blasted rock	35	50	70

Table IX. Typical angledozer output on sidehill roadway construction

Angledozers					
Linear feet of sidehill roadway construction per hour					
Slope of ground		Tractor model			
Degree	Percent	D8	D7	D6	D4
5	9	780	720	470	410
10	18	440	400	265	220
15	27	290	270	175	150
20	36	210	190	125	110
25	47	155	145	95	80
30	58	120	110	70	62

25. SUPERVISION FOR MAXIMUM WORK OUTPUT. Supervisors responsible for obtaining maximum dozer efficiency should keep the following considerations in mind.

a. Selection of dozer. There are three types of dozers from which to choose. They are bulldozers, angledozers, and tiltdozers. Tiltdozer and angledozer work should be planned so the operator does not have to stop frequently to adjust the position of the bowl. To obtain maximum work output, it is necessary to study requirements before work begins.

(1) *Bulldozer.* (*a*) *Description.* The bulldozer is the conventional dozer with the bowl and blade at right angles to the long axis of the tractor. The bowl can be raised or lowered and tilted slightly but not angled. (See fig. 49.)

(*b*) *Performance.* The bulldozer is most efficient for straight drifting of material. In most operations, the bulldozer can equal the angledozer in work output. Its bowl capacity is smaller but it can continually carry a full load with greater speed. Good tractor-dozer balance is achieved because the bowl is mounted close to the front end of the tractor.

(2) *Angledozer.* (*a*) *Description.* The angledozer is designed so the bowl and blade can be angled at 30° to the long axis of the tractor or can be used straight across the front of the tractor as a bulldozer. (See fig. 49.) The angledozer bowl can be tilted a small amount but must be angled first. It can be raised and lowered in every position.

(*b*) *Performance.* The angledozer is most efficient for making sidehill cuts. In straight dozing work, angledozer bowls normally cannot drift a full load of earth because of their large size, and it is frequently necessary to engage and disengage the steering clutches to prevent stalling. This, coupled with poor tractor-angledozer balance, causes inefficiency and excess wear on tractor parts.

(3) *Tiltdozer.* (*a*) *Description.* The tiltdozer bowl is mounted at right angles to the long axis of the tractor and cannot be angled. It is designed so either end of the blade can be tilted 12 inches below the other and the top of the bowl can be pitched forward or back. (See fig. 49.)

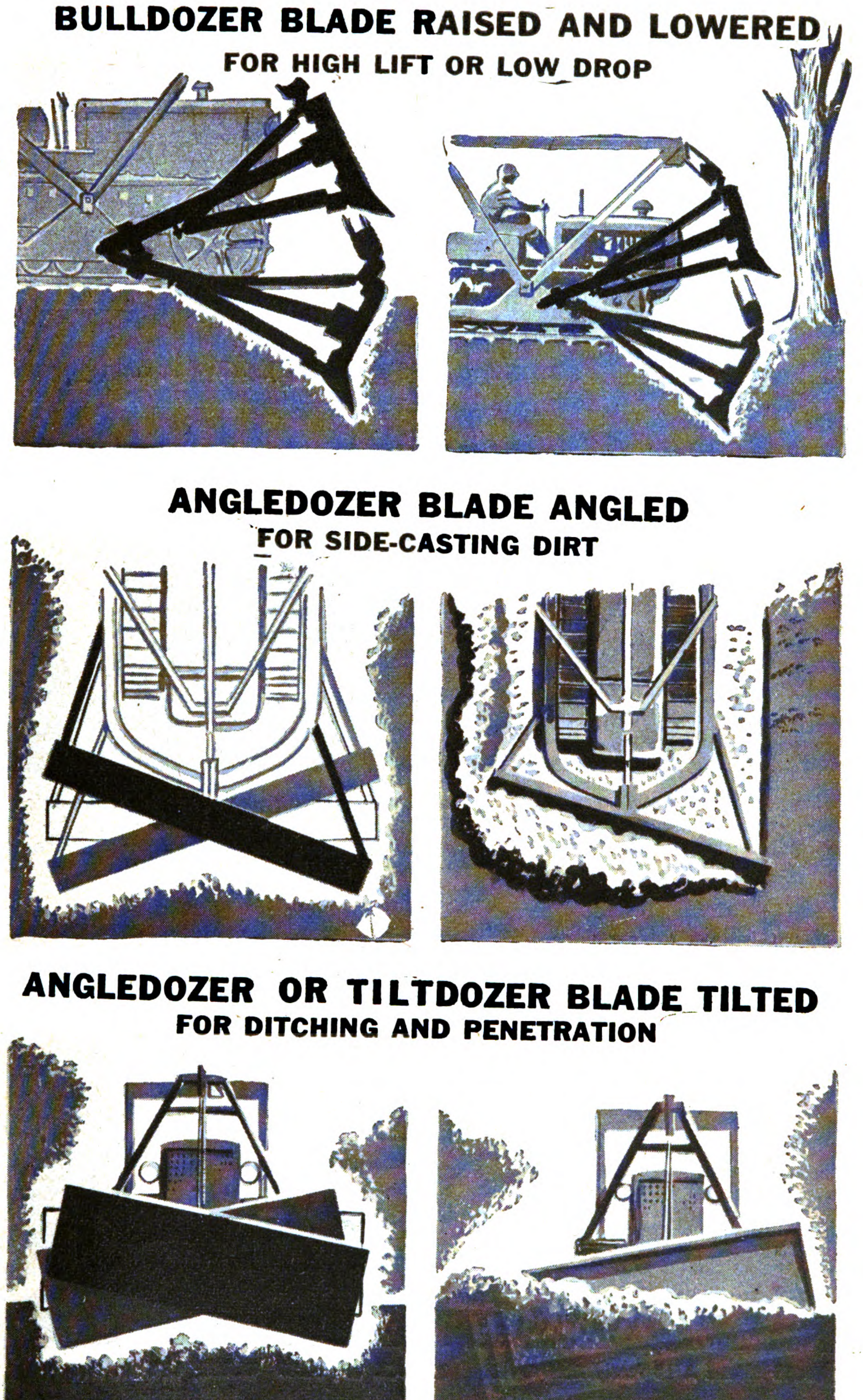


Figure 49. Dozer blade positions for various operations.

(*b*) *Performance.* In most earth-moving operations, the tiltdozer is comparable to the bulldozer. In sidehill cutting, tiltdozer work output is equivalent to angledozer output. The tiltdozer gives excellent tractor-dozer balance which results in ease of operation and a minimum of tractor maintenance. The advantages of changing the pitch of the blade are:

1. When top of bowl is pitched to rear, blade cuts better, a particularly helpful feature in compacted material.

2. When top of bowl is pitched forward, bowl carrying capacity is increased and it is easier to carry uncompacted material forward smoothly and evenly.

b. Construction operations. The following methods are normally most efficient for certain common operations.

(1) *Clearing.* Figures 50, 51, and 52 show methods of clearing brush

CLEARING
BRUSH AND SMALL TREES

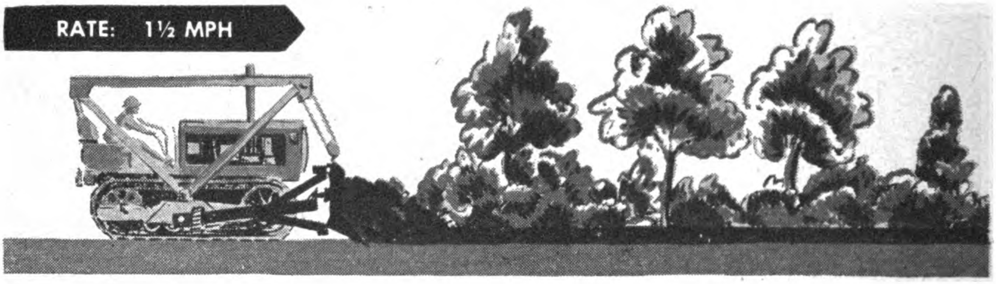
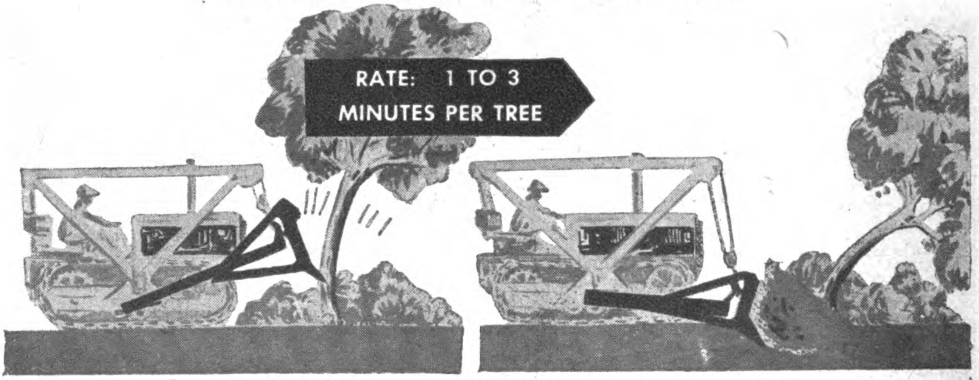


Figure 50. Method of clearing brush and small trees. Tractor drops blade below ground and moves forward until blade becomes clogged with roots and brush. Tractor backs up to clear blade and then pushes material to pile or windrow at one side of clearing. Process is repeated until area is cleared.

CLEARING
MEDIUM TREES - 4 TO 10 INCHES



1. RAISE BLADE AND PUSH TREE OVER 2. BACK UP, DROP BLADE, LIFT ROOTS FREE

Figure 51. Method of removing medium trees. Caution: In operation ① back up before roots come up under blade or tractor.

LARGE TREE REMOVAL -12 TO 30 INCHES

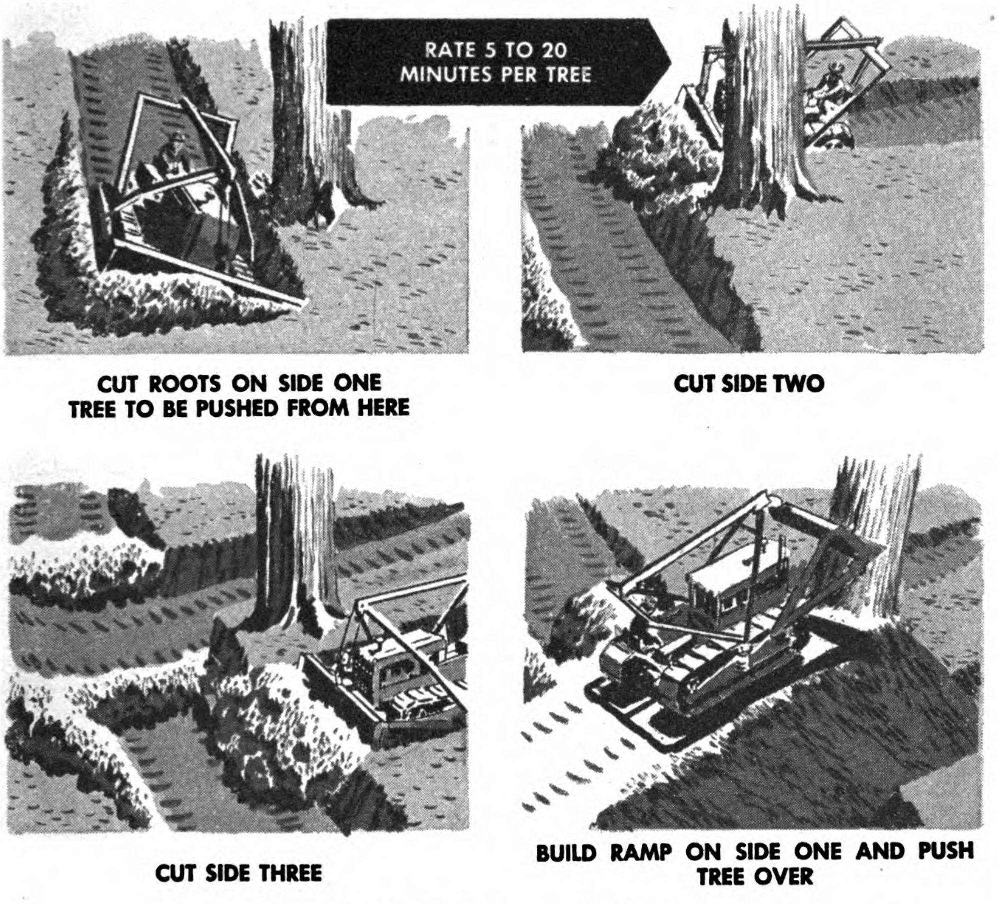


Figure 52. Method of removing large trees.

and trees. Clearing should be planned so debris is disposed of in one handling. When large trees are involved, clearing is done most efficiently by first removing brush and small trees. If burning is required, hauling can be avoided by piling and burning material at the site.

(2) *Stripping.* Stripping operations are planned to minimize haul distance; material should not have to be moved over 300 feet. Figure 53 illustrates a typical plan for efficient stripping.

(3) *Backfilling.* Dozers are the best equipment for backfilling, because material is pushed directly ahead of the machine over banks into ditches or directly against a structure. Figure 54 shows the methods used to backfill culverts, trenches, and structures. When the haul is over 150 feet, it is more efficient to have scrapers or trucks haul material directly to a fleet of dozers working continuously at backfilling. Backfilling is usually laid in loose layers from 6 to 12 inches thick, and must be thoroughly compacted.

STRIPPING

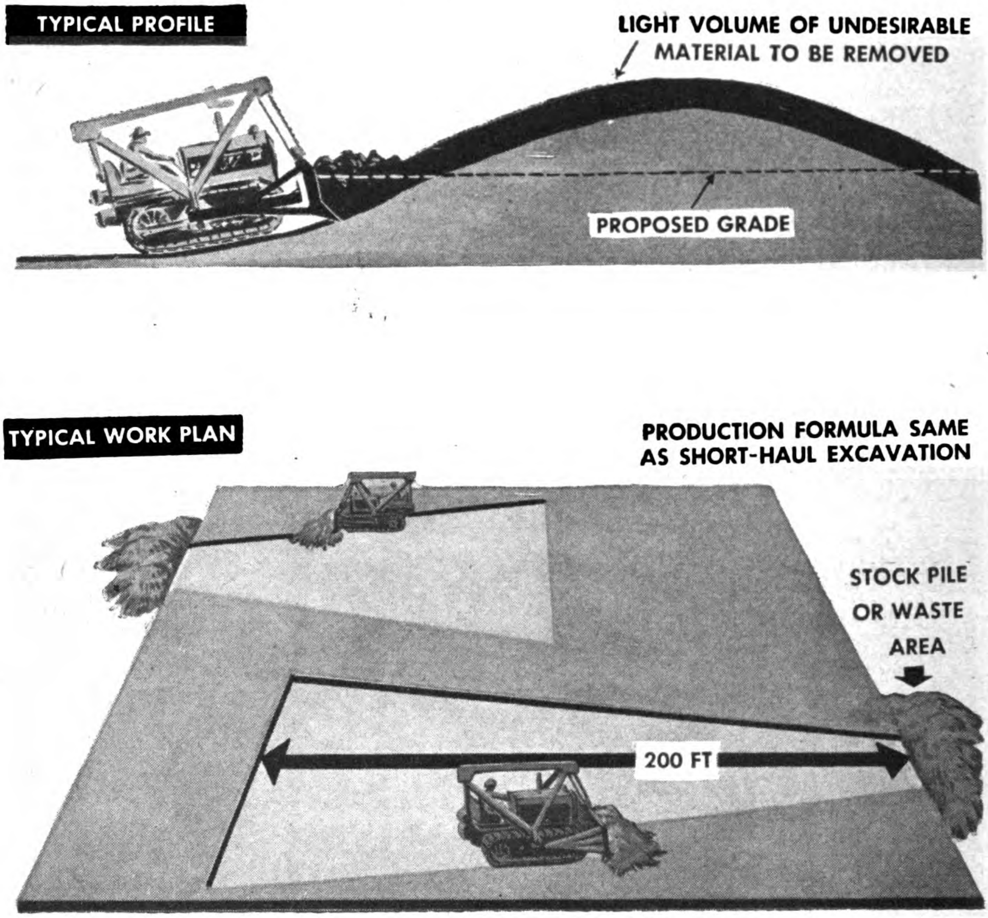


Figure 53. Typical plan for efficient stripping.

(4) *Ditching.* The V-type ditch and rough ditch are constructed efficiently by dozers.

(*a*) *V-type ditch.* The V-type ditch is constructed by an angledozer with the bowl angled and titled. (See fig. 55.)

(*b*) *Rough ditch.* Rough ditches are constructed with the dozer bowl straight across the front of a tractor working at right angles to the length of the ditch. (See fig. 55.)

(*c*) *Work output.* Rough ditches can be constructed in approximately one-half the time required to construct a V-type ditch. See figure 55 for work output of a D8 tractor with bulldozer.

(5) *Sidehill excavation.* One of the most important uses for dozers is in sidehill cutting for road construction. This includes preparing lepel benches on which scrapers can operate. (See fig. 56.)

(6) *Miscellaneous operations.* For excellent use of dozers in spreading, trimming, and finishing, see figures 57, 58, 59, and 60.

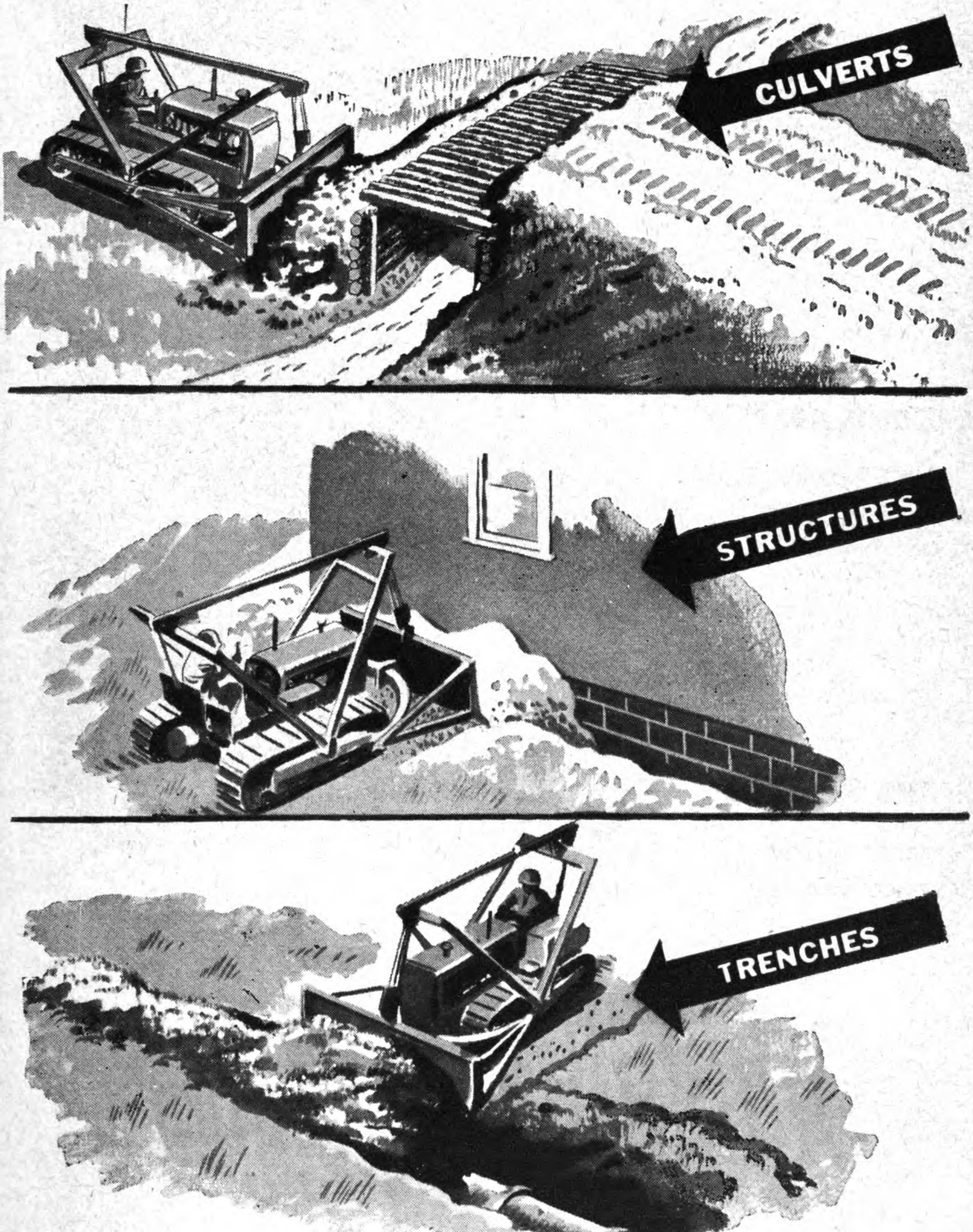
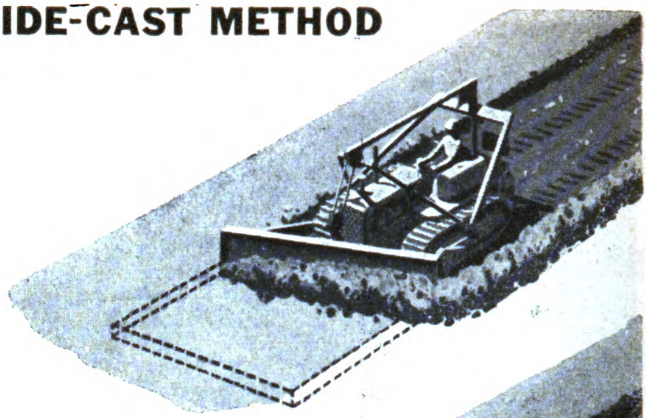


Figure 54. Method of backfilling culverts, trenches, and structures.

SIDE-CAST METHOD

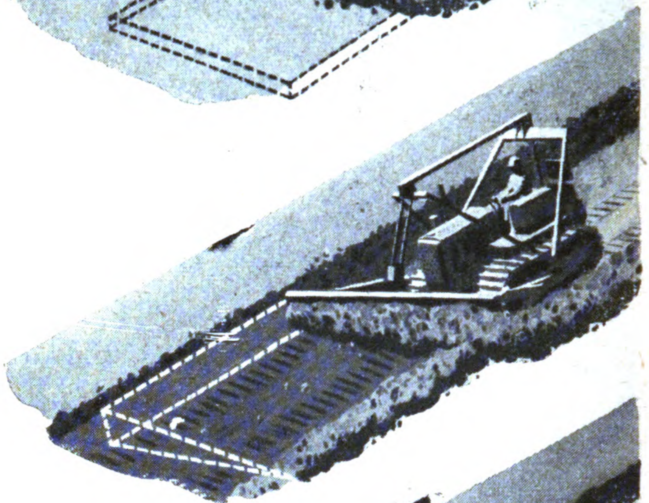
FIRST PASS

ANGLE BLADE, THROW UP WINDROW



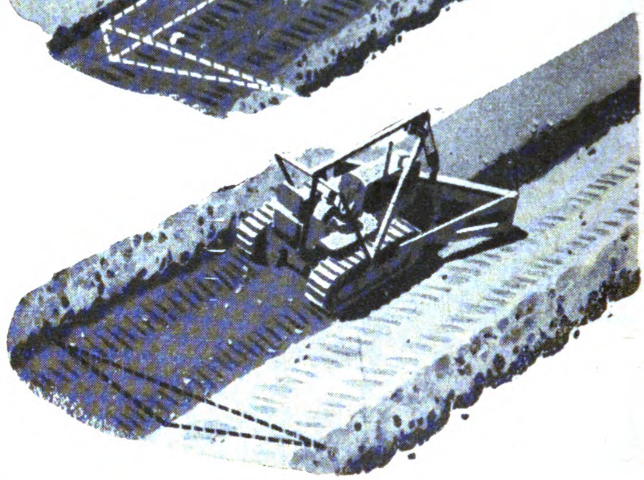
SECOND PASS

ANGLE AND TILT BLADE, PLACE TRACK ON WINDROW

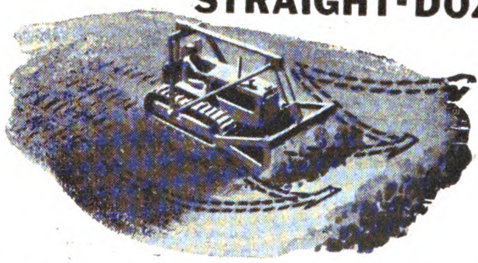


THIRD PASS

START AT BOTTOM, TRACK ON LOW SIDE



STRAIGHT-DOZING METHOD



ROUGH DITCH

WITH BLADE STRAIGHT, PUSH DIRT OUT AND UP TO ONE SIDE. REPEAT AFTER BACKING TO NEW DIGGING POSITION.

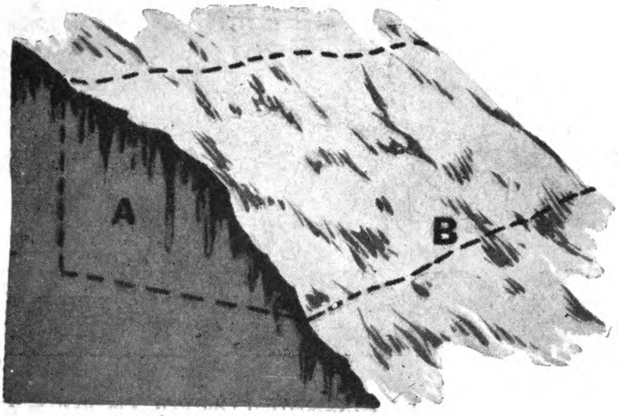
RATE: APPROX CU YD PER HOUR OF DITCH EXCAVATION WITH D8 ANGLEDOZER

SIDE-CAST METHOD,	**60**	CU YD
STRAIGHT-DOZING,	**120**	CU YD

(USE 87% OF ABOVE FIGURES FOR D7)

Figure 55. Method of constructing V-type and rough ditches.

SITE OF PROPOSED SIDEHILL CUT



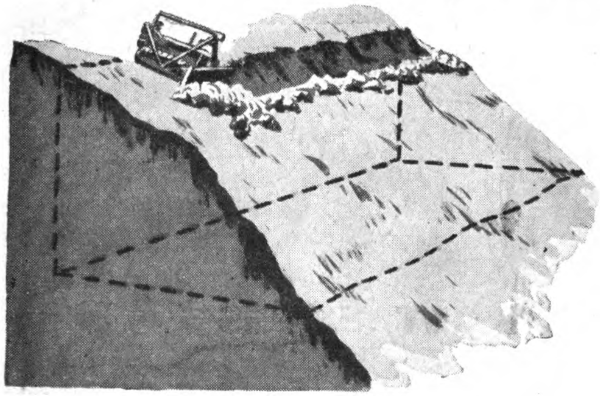
1 TO DETERMINE EXCAVATION

$$\frac{\text{AREA A} \times \text{LENGTH B}}{27} = \text{CU YD}$$

2 TO DETERMINE TIME REQUIRED

$$\frac{\text{TOTAL VOL CU YD}}{\text{ESTIMATED OUTPUT PER HR}} = \text{HR TO COMPLETE}$$

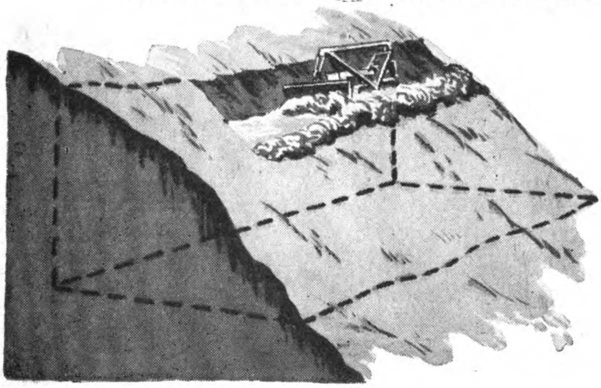
METHOD OF OPENING SIDEHILL CUT



TO OPEN CUT

1. APPROACH FROM TOP WITH BLADE STRAIGHT
2. CUT BENCH, PUSHING DIRT DOWN THE SLOPE
3. CONTINUE UNTIL BENCH IS LONG ENOUGH FOR OPERATION AS SHOWN BELOW.

METHOD OF SIDEHILL EXCAVATION



TO EXCAVATE

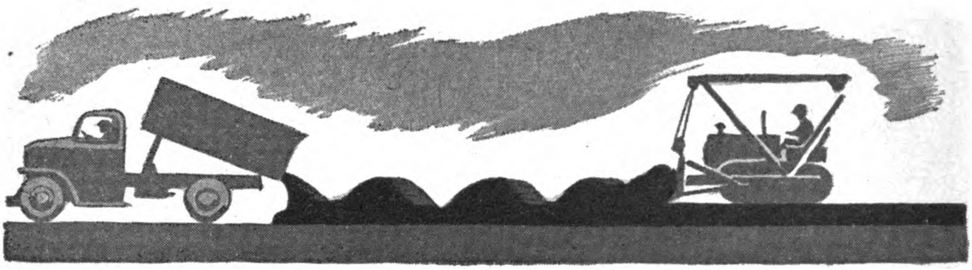
1. ANGLE BLADE FOR SIDE-CASTING
2. LOWER INSIDE CORNER OF BLADE
3. DOZER WORKS PARALLEL TO SLOPE
4. USE CUT- AND- SWING METHOD ON BENCH WIDER THAN BLADE

RATE: APPROX CU YD PER HOUR OF EXCAVATION (SIDE-CASTING 100% EFFICIENCY)
D8 ANGLEDOZER = 180 CU YD AN HR
D7 ANGLEDOZER = 170 CU YD AN HR

Figure 56. Method of sidehill excavation.

SPREADING TRUCK DUMPS

EARTH FILLS AND AGGREGATES FOR BASE COURSES



1. BLADE IN STRAIGHT POSITION
2. TRAVEL IN GEAR SUITED FOR TYPE OF SPREAD
3. ACCURATE CONTROL OF BLADE DESIRED
4. LEVELING AND SMOOTHING BY DRAGGING BLADE IN REVERSE

(Rates based on speed of tractor travel)

Figure 57. Method of spreading truck dumps.

TRIMMING CUT SLOPES

1. KEEP BLADE IN STRAIGHT POSITION
2. KEEP AREA TO BE SLOPED WITHIN BLADE REACH
3. TRIM DOWN TO LEVEL OF CUT
4. IF CUT IS HARD, BLADE CAN BE ANGLED AND EXTENDED POINT USED
5. REMOVE LOOSE MATERIAL WITH DOZER

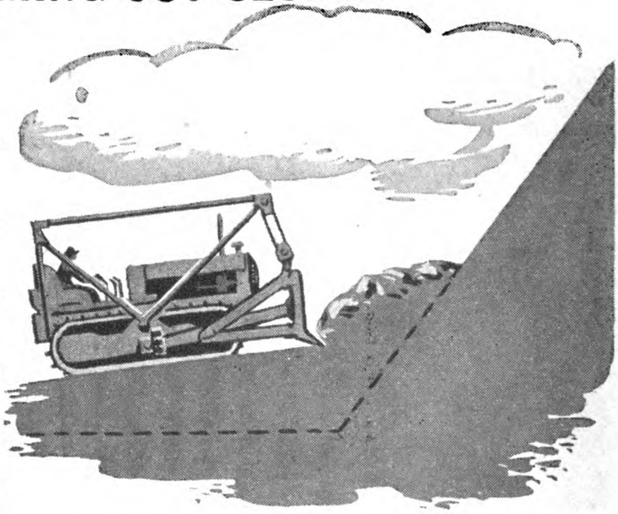
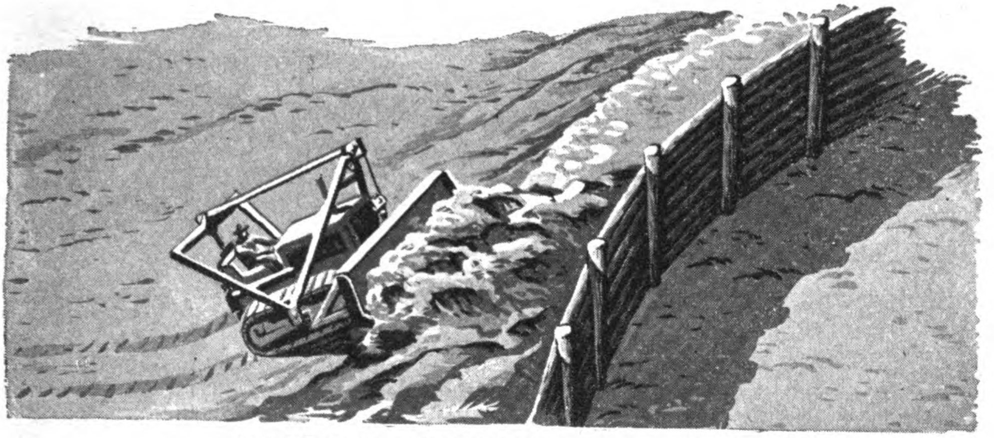


Figure 58. Method of trimming cut slopes.

BUILDING AND TRIMMING SLOPES AND REVETMENTS



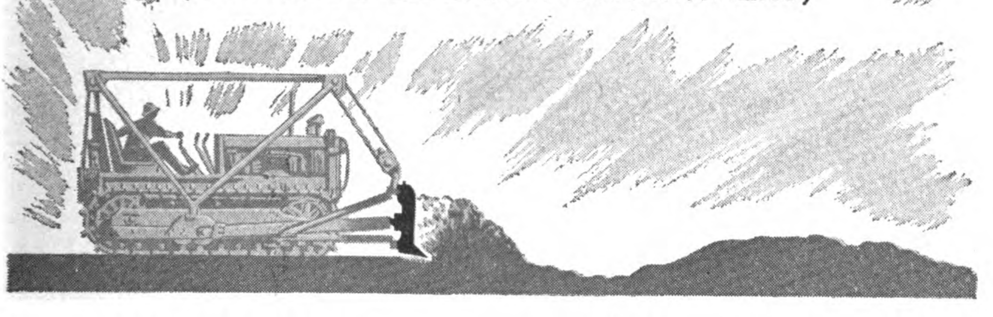
BLADE IN STRAIGHT POSITION

PUSH MATERIAL TO TOP. KEEP TOP SURFACE LEVEL

Figure 59. Method of building and trimming slopes and revetments.

EMERGENCY ROUGH FINISHING

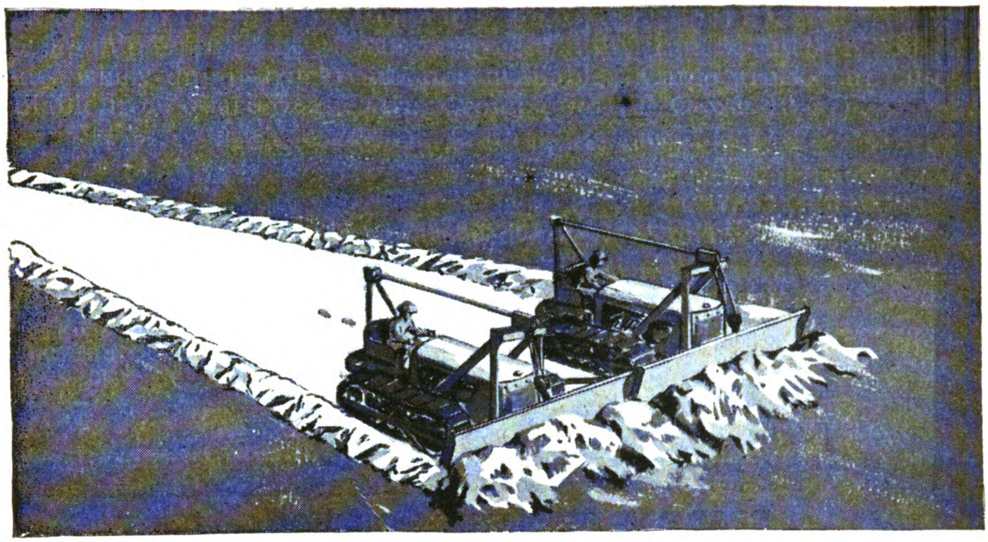
(SUBGRADE OR EARTH EMBANKMENT)



1. BLADE IN STRAIGHT POSITION
2. BEST PRACTICE TO TRAVEL IN LOW GEAR
3. ACCURATE CONTROL OF BLADE IS NECESSARY
4. LEVELING AND SMOOTHING BY DRAGGING BLADE IN REVERSE

Figure 60. Method of rough finishing.

SIDE-BY-SIDE DOZING



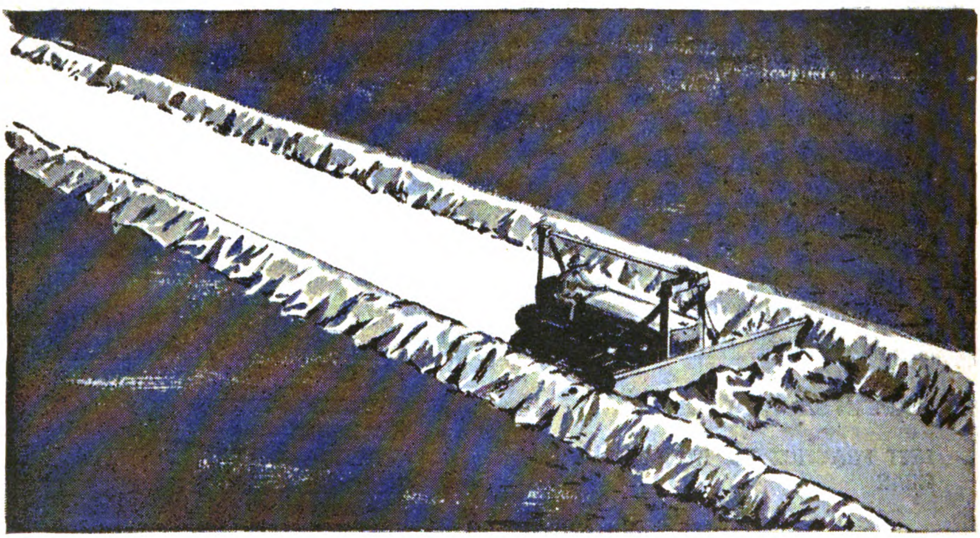
1 BLADES IN STRAIGHT POSITION

2 TWO, THREE OR FOUR TRACTORS USED

3 TRAVEL IN LOW GEAR

4 YARDAGE INCREASE BETWEEN D7 DOZER BOWLS APPROX 1 TO 1½ CU YD PER TRIP

SLOT-DOZING



1 BLADE IN STRAIGHT POSITION

2 WORK IN EXACTLY THE SAME TRACKS

3 SPILLAGE FORMS WINDROWS ON EACH SIDE WHICH RETAIN MATERIAL IN FRONT OF BOWL

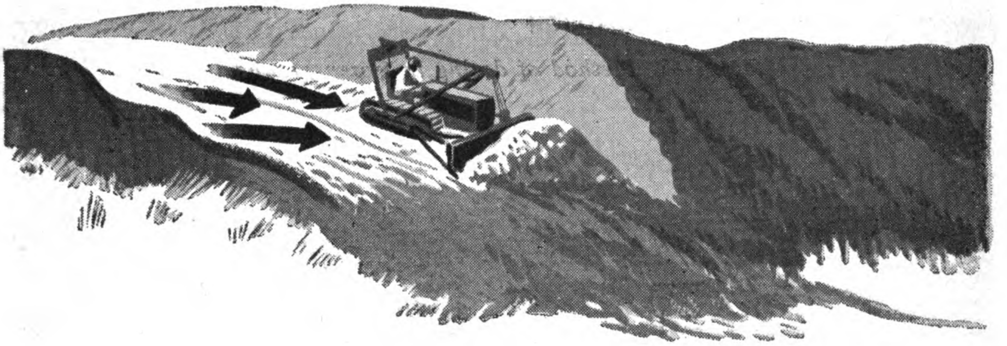
Figure 61. Method of side-by-side dozing and slot-dozing.

c. Special techniques. The following techniques save time and increase output when conditions permit their use.

(1) *Side-by-side dozing.* Side-by-side dozing gives increased output when material is to be moved 50 to 300 feet. At distances less than 50 feet, the extra yardage obtained is offset by the extra time required to maneuver the second dozer into place. (See fig. 61.)

(2) *Slot-dozing.* Slot-dozing uses spillage from the first few dozer passes to build a windrow on each side of the dozer's path. These windrows form a trench which prevents spillage on subsequent passes. (See fig. 61.)

DOWNHILL DOZING



1. **BLADE IN STRAIGHT POSITION**
2. **WORK CUT AREA TO CENTRAL POINT**
3. **MAKE FOUR OR FIVE PASSES TO BRINK OF HILL**
4. **RIDE PILE OF MATERIAL DOWN TO BOTTOM OF SLOPE WITH ONE PASS**

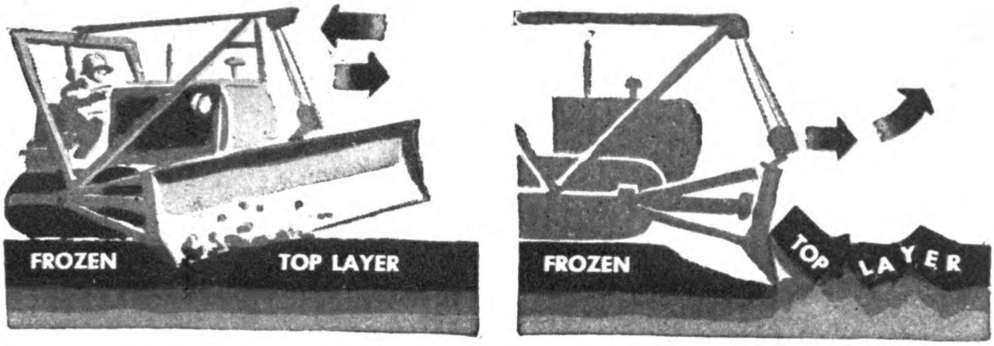
Figure 62. Method of downhill dozing.

(3) *Downhill dozing.* When dozing downhill, it is not necessary to travel down the hill with each load. Several loads can be pushed into a pile at the brink of the hill and carried to the bottom in one pass. (See fig. 62.)

(4) *Dozing frozen ground.* When operating on frozen ground, it is often difficult to break through the frozen top surface. See figure 63 for method of dozing in frozen ground. To perform the operation illustrated in figure 63 without tilting the bowl, run one truck up onto a log or ridge of dirt, causing the entire machine to tilt.

(5) *Removing rocks and boulders.* See figure 64 for method of removing large rocks or boulders.

(6) *Snow and ice removal.* In removing snow and ice, the angledozer is most effective with the bowl angled to side-cast. When removing deep snow with an angledozer, it is often necessary to supplement the forward movement of the dozer with a quick upward lift of the bowl. This operation piles snow high on the side of the dozer.



STEP ONE

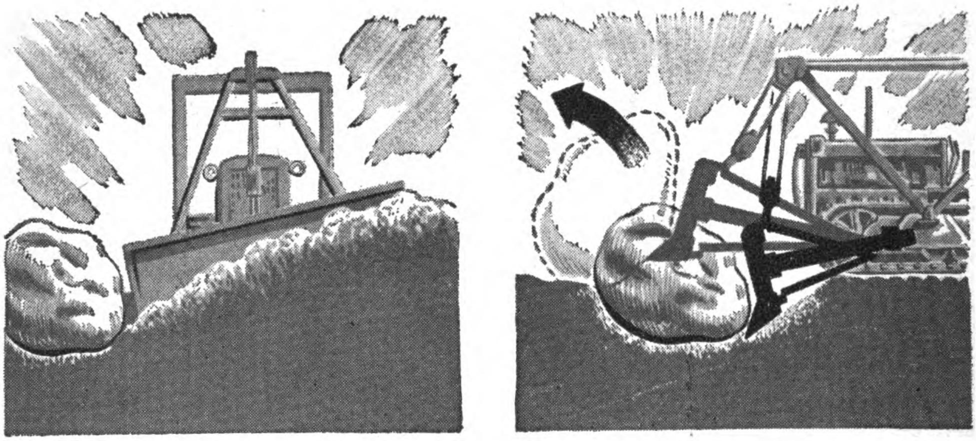
A. TILT BLADE

B. MOVE FORWARD AND BACKWARD UNTIL FROZEN LAYER IS WORN THROUGH

STEP TWO

BRING BLADE UNDER FROZEN SURFACE AND LIFT BOWL

Figure 63. Method of dozing in frozen ground.



STEP ONE

DIG AROUND ROCK

STEP TWO

A. WORK ONE CORNER OF BLADE UNDER ROCK

B. HOIST DOZER BOWL AND TRAVEL FORWARD, LIFTING OUT ROCK WITH A FORWARD ROLLING MOTION

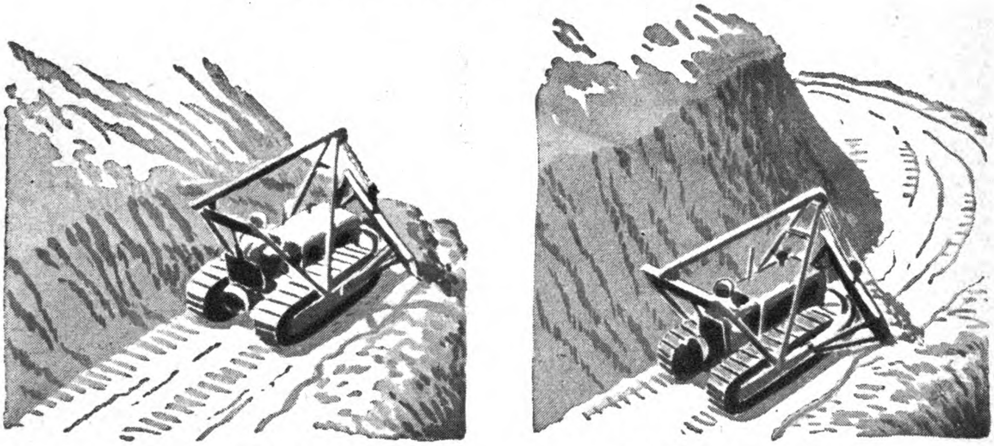
Figure 64. Method of removing large rocks and boulders.

(7) *Working up or down a vertical face.* See figures 65 and 66 for proper methods of working up or down a vertical or near-vertical face.

d. Checking performance. See figure 67 for a check list to be used in determining the efficiency of dozer performance.

SIDEHILL ROADS

WORKING FROM BOTTOM TO TOP



START

1 ANGLE BLADE, FORWARD POINT ON BANK SIDE

2 WITH BLADE RAISED, DIG OUT BANK

FINISHED ROAD

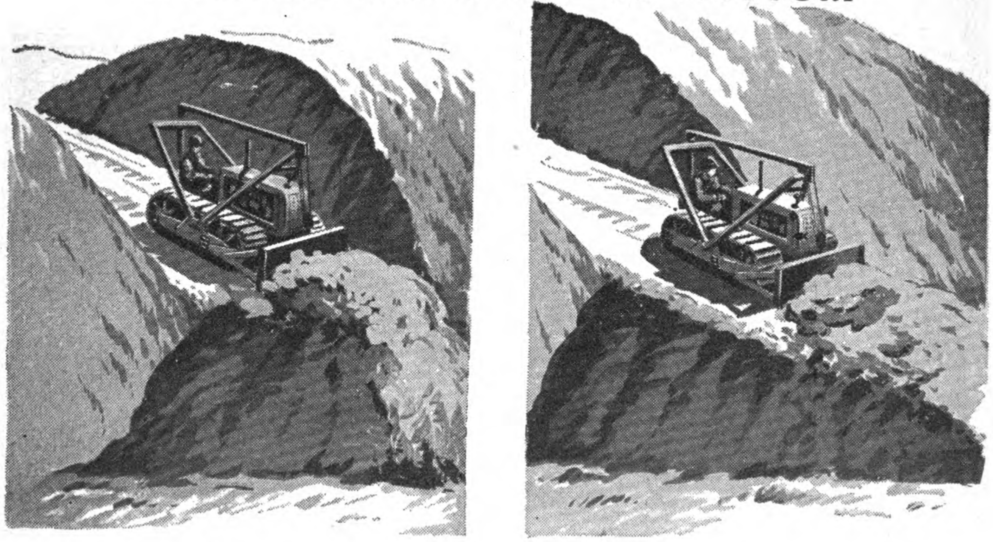
3 BACK UP AND SPREAD FALLEN MATERIAL TO FORM RAMP UPGRADE

4 REPEAT DIGGING INTO BANK AS RAMP IS BUILT

5 FINISH WITH IN-TILT

Figure 65. Working up a near-vertical face.

WORKING FROM TOP TO BOTTOM



MAKE REPEATED TRIPS TO BRINK OF SLOPE UNTIL FILL BUILDS UP TO EDGE OF CUT

RIDE DOZER TO BOTTOM OF FILL

Figure 66. Working down a near-vertical face.

CHECK DOZER PERFORMANCE BY THESE RULES

LOADS

ARE THEY HEAPED?

IS THE TRACTOR MOTOR KEEPING UP A FULL RPM, YET WORKING FULLY?

TRAVEL

IS APPROX 1.5-MPH HAUL SPEED MAINTAINED?

IS BACK-UP SPEED MADE IN AS HIGH GEAR AS POSSIBLE?

ARE HAUL DISTANCES KEPT DOWN TO 200 TO 300 FT?

ARE LOADS DOZED IN TRENCH WHERE POSSIBLE?

IS DOWNHILL DOZING MAINTAINED?

SPREADING

IS TIME BEING WASTED AFTER SPREAD IS MADE?

MECHANICAL

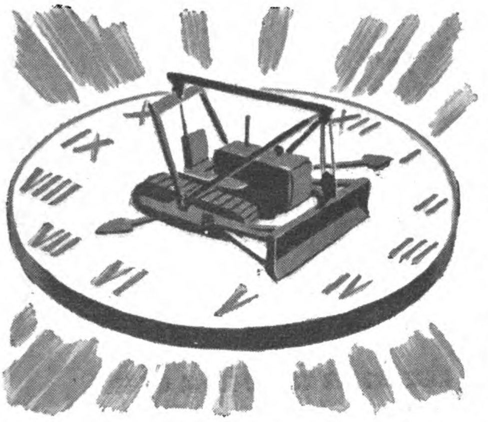
ARE ALL ADJUSTMENTS TO POWER UNIT BEING MAINTAINED?

ARE BLADES IN GOOD CONDITION?

SHEAVES IN ALIGNMENT?

CABLE RUNNING FREE?

PERFORMANCE = TIME



BATTLES ARE WON OR LOST IN MINUTES. TIME DEPENDS ON PERFORMANCE. PERFORMANCE DEPENDS ON . . .

THE RIGHT **MACHINE** FOR THE JOB

THE RIGHT **OPERATOR**

THE RIGHT **PLANNING**

THE RIGHT **PROCEDURE**

THE RIGHT **MAINTENANCE**

Figure 67. Check list to determine efficiency of dozer performance.

26. PHYSICAL CHARACTERISTICS. See table X for data on dimensions, weights, operating speeds, transportation, and fuel and oil consumption of scrapers.

27. USE OF SCRAPERS. a. Purpose. Scrapers, either tractor-drawn or motorized, are earth-moving machines capable of digging and loading, hauling, and dumping and spreading. They are designed to make shallow cuts, haul the material for a considerable distance, and spread it in thin layers. Where digging is difficult, they are sometimes supplemented by tractor-drawn rooters to loosen earth or pusher tractors to aid in digging and loading to capacity.

b. Controlling factors. Use of scrapers is controlled primarily by the size of the project, the type of material, and the length of haul.

(1) Scrapers are most effective on large earth-moving jobs such as airdromes and roads through rolling country.

(2) Scrapers dig and load light and medium soils relatively free from root masses, stumps, or boulders. Heavy soils or consolidated soils require supplemental use of pusher tractors or tractor-drawn rooters. Dry sands without binder will not pile up in scraper bowls. Extremely wet or muddy soils are sticky and make it difficult to discharge scrapers.

(3) Tractor-drawn scrapers are efficient on hauls between 300 and 1,500 feet. At 900- to 5,000-foot haul distances motorized scrapers become more efficient because of their higher speed. Bulldozers and angledozers exceed scrapers in efficiency on hauls less than 300 feet. Power shovels of ½- to ¾-cubic-yard capacity working with dump trucks equal or exceed tractor-drawn scrapers in efficiency at hauls greater than 1,500 feet and equal or exceed motorized scrapers in efficiency at hauls over 3,500 feet. These haul lengths are approximate and depend largely on type of material, site conditions, and skill of operators.

28. ESTIMATING WORK OUTPUT. a. Work output formula. The following formula is used to estimate scraper output in cubic yards per hour:

$$\text{OUTPUT} = \frac{Q \times f \times 60 \times E}{Cm}$$ (in cubic yards, either *in-place* or *compacted* depending on conversion factor f)

Where, Q = bowl capacity in *loose* cubic yards.
f = soil conversion factor.
60 = minutes per hour.
E = the scraper efficiency.
Cm = total cycle time in minutes.

(1) *Bowl capacity (Q).* Bowl capacity is expressed either as struck capacity or heaped capacity. Struck capacity is the volume of earth a scraper will carry when earth is leveled to the top of the bowl. (See fig. 68.) Heaped capacity is the volume of earth a scraper will carry when material is heaped to the maximum in the center of the bowl. (See fig. 68.) In earth-moving operations, scrapers should be filled to

Table X. Physical characteristics of scrapers

Equipment	Weight		Over-all dimensions			Capacity		Method and speed of transport		Fuel consumption	
	Empty (lb)	Loaded (lb)	Length (in)	Width (in)	Height (in)	Struck (yd)	Heaped (yd)	Long distance	Operation	Fuel	Oil (lubricating)
Scraper, road, towed, cable-operated, 12-cubic-yard	19,700	55,000[1]	386	122	131	12	15	Truck Rail (10–15 mph towed)	Tractor (See table IV for tractor speeds)	----------	------
Scraper, road, motorized, cable-operated, 12-cubic-yard	30,500	65,800	386	122	131	12	15	Truck Rail Own motive power (15 mph)	Own motive power	5-gal per hr (Diesel oil)	.12 gal per hr
Scraper, road, towed, cable-operated, 8-cubic-yard	14,000	38,750	355	94	95	8	11	Truck Rail (10–15 mph towed)	Tractor (See table IV for tractor speeds)	----------	--------
Scraper, road, towed, hydraulically operated, 1½-cubic-yard	2,400	6,800	172	70	55	1½	2	Airborne Truck Rail (40–45 mph towed)	Tractor (See table IV for tractor speeds)	----------	--------

[1] Scraper is loaded to struck capacity (12 cubic yards) with soil weighing 110 pounds per cubic foot.

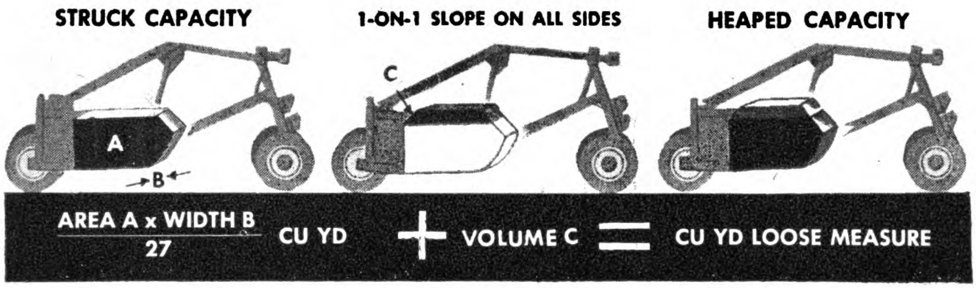


Figure 68. Method of determining heaped capacity of scrapers.

heaped capacity, and this capacity should normally be used as a basis for performance calculations.

(2) *Conversion factor (f)*. The *loose* yards carried by the scraper can be converted to either *in-place* yards or *compacted* yards by use of the proper conversion factor, see table II and paragraph 17.

(3) *Scraper efficiency factor (E).* The scraper efficiency factor takes into account the fact that a full 60-minute work hour is rarely attained. Efficiency varies depending on supervision, operators, maintenance requirements, and site conditions. Experience shows that the average value of 80 per cent used in the example in figure 69 is normal, but it must be checked on each job by observation and experience.

(4) *Cycle time (Cm).* Total cycle time in minutes consists of fixed time elements and variable time elements as follows:

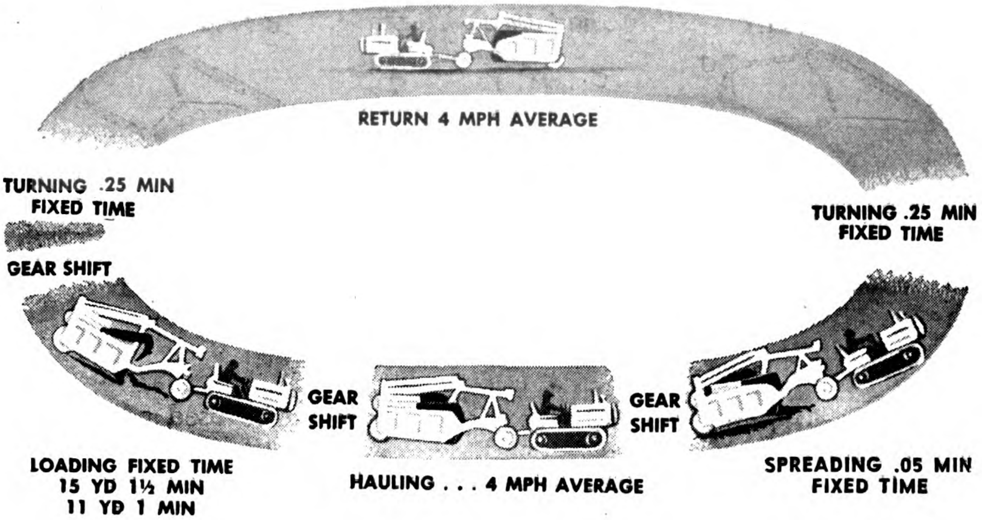
(*a*) *Fixed time elements.* The total time required for digging and loading, dumping and spreading, and turning and gear shifting is independent of the length of haul and varies only slightly with different prime-mover-scraper combinations, site conditions, and characteristics of excavated materials. This time averages between 2 and 5 minutes.

(b) *Variable time elements.* The time required for travel between the excavation and the spreading area can be estimated on the basis of travel speed in different gears and the haul distance traveled in each gear. For speeds of different tractor models, see table IV. The motorized scraper should haul at 14 to 15 mph for greatest efficiency.

b. Tables of typical work output. Tables XI and XII give the average work output in cubic yards per hour of the 8-cubic-yard and 12-cubic-yard tractor-drawn scrapers for different soil types, lengths of haul, and motive power. These yardages can be obtained only when all conditions are favorable. They should be used as a guide for estimating scraper performance, not as a table of output to be expected on every job. Similar data is given in table XIII for the 12-cubic-yard motorized scraper.

29. SUPERVISION FOR MAXIMUM WORK OUTPUT. Supervisors responsible for obtaining maximum scraper efficiency should keep the following considerations in mind.

a. Loading. Loading should be done in minimum time without excessive stress on tractor or scraper. Normally, heaped loads should be obtained. However in some soil types, the last 2 or 3 yards of a heaped load may require more time to load than is justified, and a few extra trips will save time. See figures 70, 71, and 72 for special tech-



EXAMPLE PROBLEM

GIVEN: 8-CU-YD SCRAPER (11-CU-YD HEAPED) WITH D7 TRACTOR
AVERAGE HAUL DISTANCE ONE WAY=600 FT
COMMON EARTH
EFFICIENCY FACTOR OF 80%
SOIL CONVERSION FACTOR (LOOSE TO COMPACTION)=0.72 SEE TABLE

DETERMINE: COMPACTED CUBIC YARDS MOVED PER HOUR

STEP I DETERMINE FIXED TIME

LOADING	1.00 MIN
SPREADING	0.50 MIN
TURNING	0.50 MIN
GEAR SHIFTS	0.50 MIN
TOTAL FIXED TIME	2.50 MIN

STEP II DETERMINE VARIABLE TIME

TRAVEL 1,200 FT AT 4.0 MPH

$$\frac{1{,}200 \times 60}{4 \times 5{,}280} = 3.4 \text{ MIN}$$

STEP III ADD FIXED AND VARIABLE TIME

TOTAL CYCLE TIME=2.50+3.40=5.9 MIN

STEP IV SUBSTITUTE IN WORK-OUTPUT FORMULA

$$\text{OUTPUT} = \frac{\overset{(Q)}{11} \times \overset{(f)}{.72} \times 60 \times \overset{(E)}{.80}}{\underset{(Cm)}{5.9}} = 64 \text{ CU YD PER HR}$$

Figure 69. Example problem showing method of calculating scraper output.

Table XI. Output (cubic yards per hour), 8-cubic-yard scraper drawn by D7 tractor

Length of haul one-way (feet)	Per 60-minute hour	Light soil			Medium soil			Heavy soil		
		Grade			Grade			Grade		
		0	5% down	10% down	0	5% down	10% down	0	5% down	10% down
400	Round trips	14.0	14.0	14.3	14.0	14.6	15.4	14.6	15.4	16.2
	Cubic yards[1]	118	129	142	118	128	136	112	118	125
500	Round trips	12.5	12.5	12.8	12.5	13.0	13.6	13.0	13.6	14.3
	Cubic yards	105	115	127	105	114	120	101	105	110
600	Round trips	11.5	11.5	11.8	11.5	12.0	12.5	12.0	12.5	13.0
	Cubic yards	97	106	117	97	106	110	92	96	100
700	Round trips	10.7	10.7	10.9	10.7	11.1	11.5	11.1	11.5	12.0
	Cubic yards	90	98	108	90	98	101	86	88	92
800	Round trips	9.8	9.8	10.0	9.8	10.2	10.5	10.2	10.5	10.9
	Cubic yards	82	90	99	82	90	92	79	81	84
1,000	Round trips	8.6	8.6	8.7	8.6	8.8	9.1	8.8	9.1	9.4
	Cubic yards	72	79	86	72	77	90	68	70	72
1,200	Round trips	7.6	7.6	7.7	7.6	7.8	8.0	7.8	8.0	8.2
	Cubic yards	64	70	76	64	69	70	60	62	63
1,500	Round trips	6.5	6.5	6.6	6.5	6.7	6.8	6.7	6.8	7.0
	Cubic yards	55	60	65	55	59	60	52	52	54

[1] Output is in terms of *in-place* yards; scraper loaded to *heaped* capacity.

Table XII. Output (cubic yards per hour), 12–cubic-yard scraper

Length of haul one-way (feet)	Per 60-minute hour	Light soil				Medium soil				Heavy soil			
		Grade				Grade				Grade			
		0	5% down	10% down	0	0	5% down	10% down	0	0	5% down	10% down	0
		D8 Tractor			D7 Tractor D7 Pusher	D8 Tractor			D7 Tractor D7 Pusher	D8 Tractor			D7 Tractor D7 Pusher
400	Round trips	13.32	12.78	13.02	13.32	13.02	12.70	13.32	13.63	13.02	13.32	13.62	13.95
	Cubic yards[1]	139	144	158	173	136	143	160	163	136	140	143	146
600	Round trips	11.10	10.71	10.90	11.10	10.90	10.73	11.10	11.31	10.90	11.10	11.31	11.53
	Cubic yards	115	121	132	143	113	121	133	136	113	117	119	121
800	Round trips	9.53	9.23	9.38	9.67	9.38	9.24	9.53	1.84	9.38	9.53	9.68	10.00
	Cubic yards	99	104	114	126	97	103	114	118	97	100	102	105
1,000	Round trips	8.23	8.00	8.12	8.45	8.12	7.98	8.23	8.57	8.12	8.23	8.34	8.70
	Cubic yards	86	90	99	110	84	90	99	103	84	86	87	91
1,200	Round trips	7.22	7.15	7.23	7.50	7.23	7.10	7.32	7.60	7.23	7.32	7.41	7.70
	Cubic yards	76	80	88	97	75	80	88	91	75	77	78	81
1,500	Round trips	6.25	6.12	6.19	6.45	6.19	6.13	6.25	6.53	6.19	6.25	6.32	6.60
	Cubic yards	65	69	75	84	64	69	75	78	64	66	66	69
2,000	Round trips	5.04	4.96	5.00	5.22	5.00	4.96	5.04	5.26	5.00	5.04	5.08	5.31
	Cubic yards	53	56	61	68	52	56	61	63	52	53	53	56

[1] Output is in terms of *in-place* yards; scraper loaded to *heaped* capacity.

Table XIII. Output (cubic yards per hour), 12–cubic-yard motorized scraper

Haul one-way (feet)	Light soil		Medium soil		Heavy soil	
	Round trips	Cubic yards[1]	Round trips	Cubic yards	Round trips	Cubic yards
600	13.6	184[2]	15.0	180	14.3	150
800	12.8	172	14.0	168	13.3	140
1,000	12.0	162	13.0	156	12.5	131
1,200	11.1	150	12.0	144	11.5	121
1,400	10.5	142	11.3	136	10.9	114
1,600	10.0	135	10.7	129	10.4	109
1,800	9.5	128	10.2	122	9.8	102
2,000	9.1	123	9.7	116	9.4	99
2,500	8.0	108	8.4	101	8.2	86
3,000	7.2	98	7.4	91	7.4	78
3,500	6.6	89	6.9	83	6.7	70
4,000	6.1	83	6.3	76	6.2	65
4,500	5.6	76	5.8	70	5.7	60
5,000	5.2	70	5.4	65	5.3	56

[1] Production is based on good working conditions and efficient operation. Scraper is pusher loaded on level by D8 tractor.
[2] Output is in terms of *in-place* yards; scraper loaded to *heaped* capacity.

niques to be followed in loading different soil types, rooted material, boulders, and stumps. In planning loading, the following methods and factors should be taken into account:

(1) *Downhill loading.* Downhill loading uses the force of gravity acting on the tractor, scraper, and load to obtain larger loads in less time. It should be used in a cut wherever possible. See figure 73. The following rule of thumb is used to estimate the effect: the gravity force is 20 pounds pull per gross ton of weight per 1 per cent of downhill grade. The same rule can be used to calculate the disadvantageous effect of uphill travel.

Example: A tractor-scraper combination weighing 50 tons loading down a 10 per cent grade has the normal drawbar pull of the tractor plus 20 pounds additional pull for every ton ($20 \times 50 = 1{,}000$) times 10 (percent grade) or 10,000 pounds of additional pull. This pull will add more material per load and the added material will, in turn, add further to the total gravitational force.

(2) *Straddle loading.* When it is necessary to load on the level, as in light cuts, stripping, and the like, *straddle loading* (fig. 73) can be used to increase yardage per trip. This method gains yardage on every third trip because the center strip loads with less resistance than a full cut.

(3) *Combining downhill and straddle loading.* Maximum efficiency is obtained when the downhill and straddle-loading techniques are combined.

b. Hauling. Maximum efficiency in hauling is extremely important since this operation requires more time than any other. The following factors should be considered:

(1) *Unfavorable grades.* As many grades as possible should be eliminated to permit maximum travel in high gear. For travel speeds

Figure 70. Method of loading various types of soil.

in different gears, see table IV. Grade reduction or building long easy grades is not always helpful, as it may be more efficient to climb a steep, short grade in low gear than to travel a long moderate grade in an intermediate gear. See figure 74 for computations showing the effect on production of steep, poorly maintained haul roads.

(2) *Maintenance of haul roads.* Well-maintained haul roads eliminate vibration, shock, and wear on both operator and machine. They will reduce equipment maintenance and increase operator efficiency.

(3) *Elimination of turns.* Methods for increasing production by

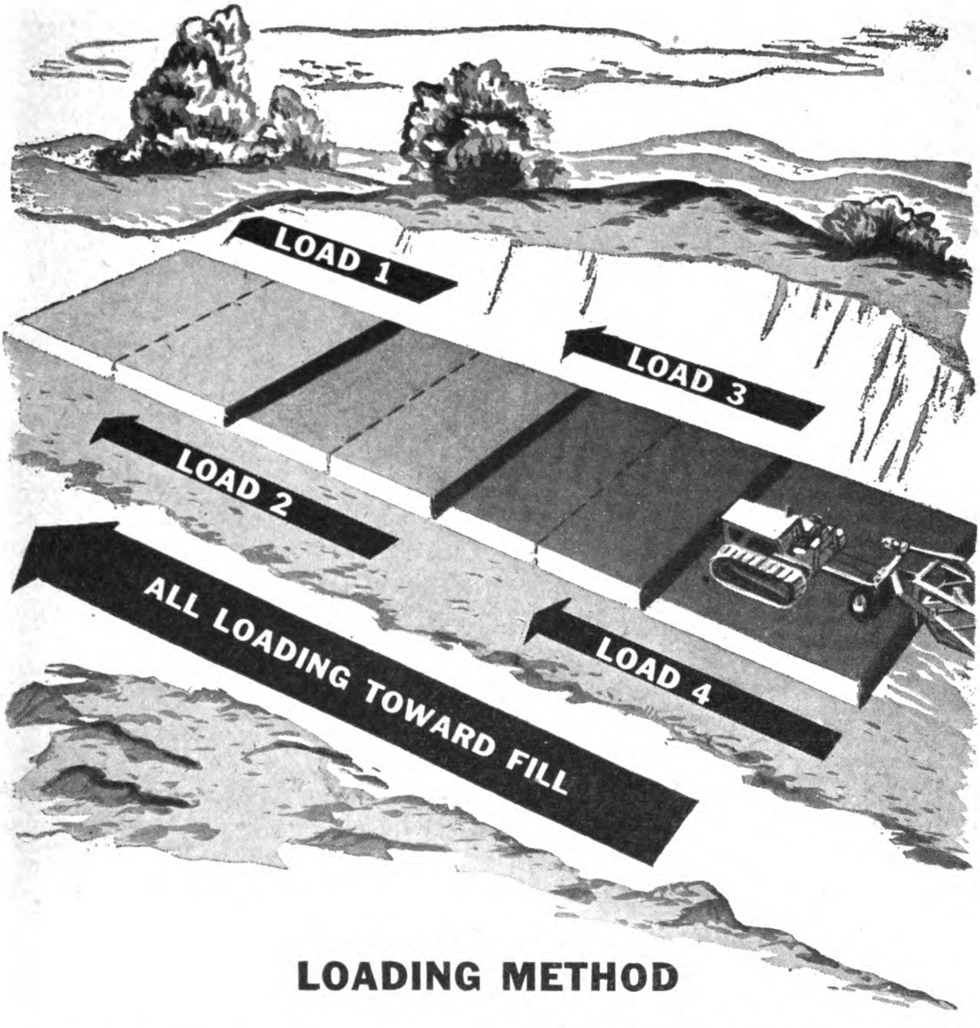


Figure 71. Method of loading rooted material.

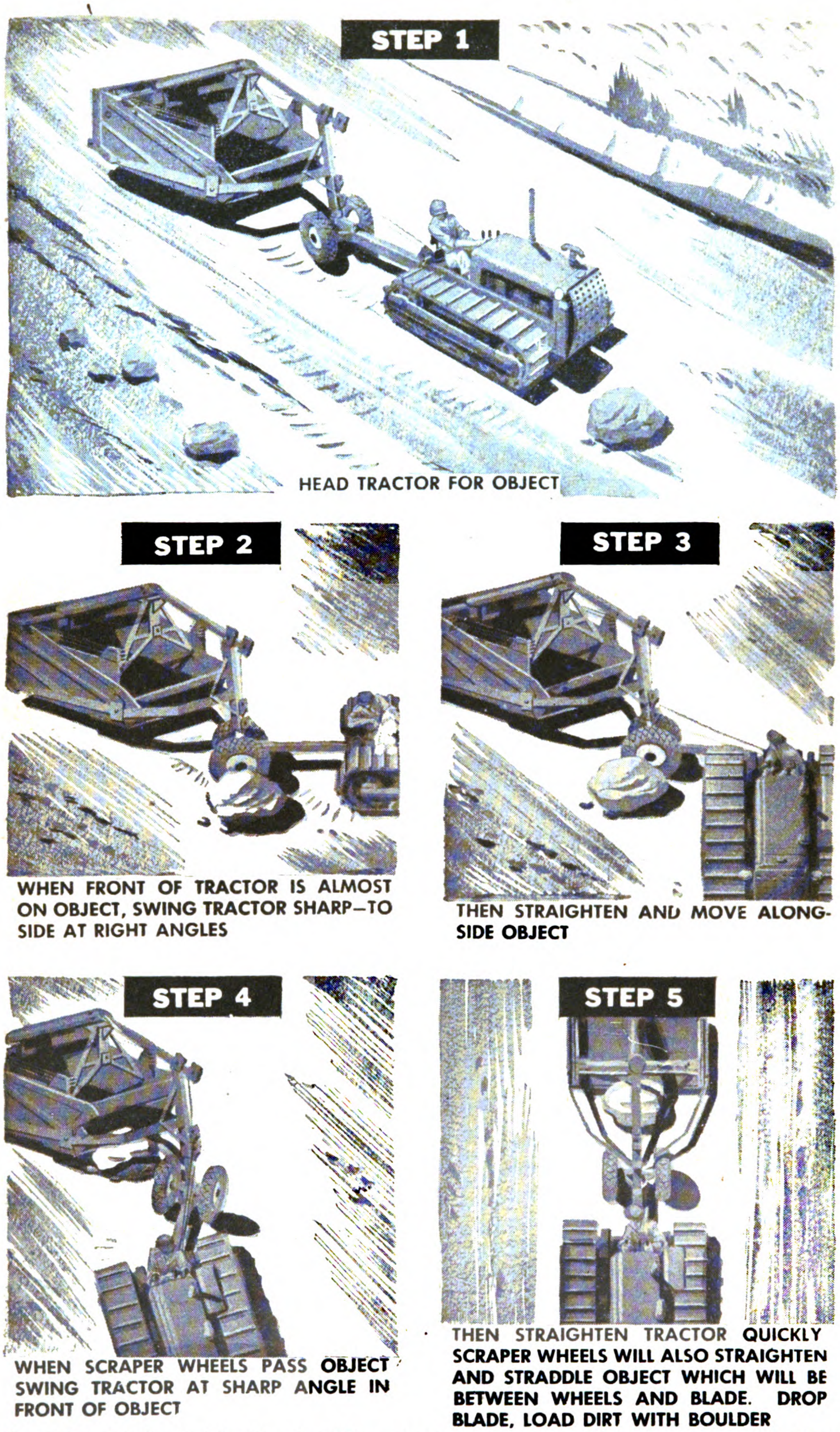
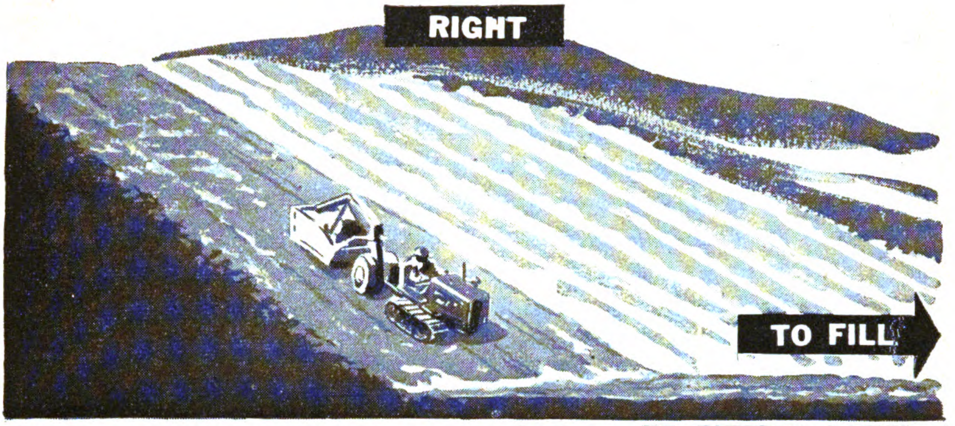
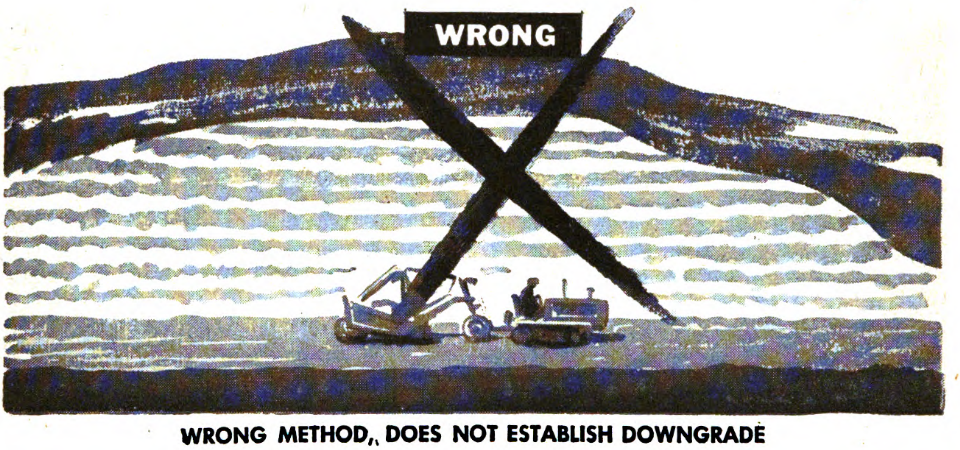


Figure 72. Method of loading boulders or other material without running over object with tractor or front wheels of scraper. Drive slowly to prevent damage to scraper. Remove the object by other means when practicable.

DOWNHILL LOADING

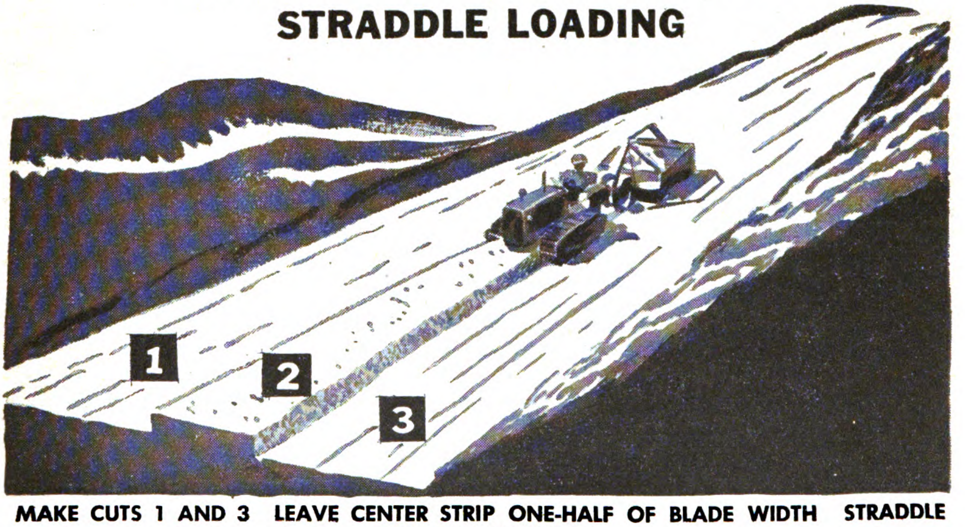


START AT TOP, WORK CUT TOWARD FILL WORK CUTS IN LAYERS FROM BACK TO FRONT OF CUT



WRONG METHOD,, DOES NOT ESTABLISH DOWNGRADE

STRADDLE LOADING



MAKE CUTS 1 AND 3 LEAVE CENTER STRIP ONE-HALF OF BLADE WIDTH STRADDLE STRIP AND MAKE CUT

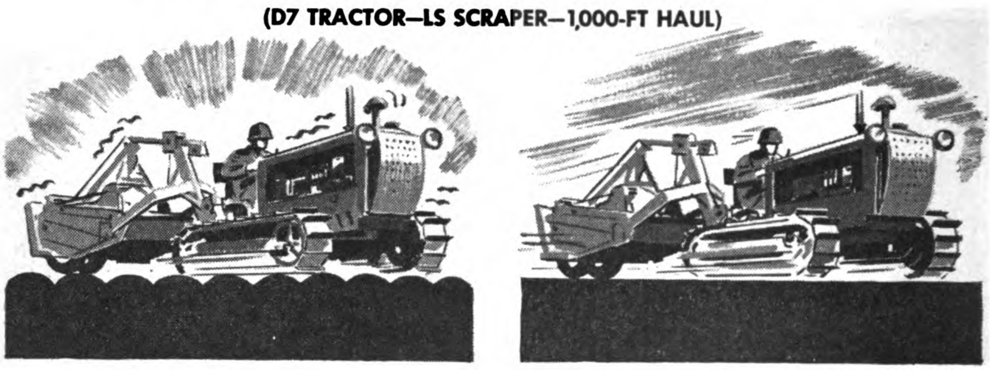
Figure 73. Downhill and straddle loading to increase yardage per trip.

eliminating unnecessary turns in hauling operations are shown in figure 75.

(4) *Tire inflation.* Proper scraper tire inflation is necessary to obtain maximum effectiveness from tractor drawbar pull. Every inch of scraper-tire penetration into the ground requires 30 pounds additional pull per gross ton of scraper weight. To decrease penetration tires can be deflated as low as 20 pounds without harmful effect. Proper tire pressures are obtained by observing penetration and making the necessary corrections.

THE EFFECT OF ROUGH GROUND ON TRACTOR TRAVEL SPEEDS

(D7 TRACTOR—LS SCRAPER—1,000-FT HAUL)



ROUGH ROADWAY		SMOOTH ROADWAY
4 TH	TRACTOR GEAR—HAUL AND RETURN	5 TH
4.6 MPH	TRACTOR TRAVEL AND SPEED	6 MPH
5 MIN.	TOTAL TRAVEL TIME—1,000 FT. HAUL	3.8 MIN
8	TOTAL TRIPS PER HOUR	9.5
75 CU YD	CU YD EXCAVATION PER HOUR	90 CU YD

SUMMARY

SMOOTH ROADWAY PERMITTING TRAVEL BOTH WAYS IN 5TH GEAR ADDS 15 CU YD PER HR OR 120 CU YD PER 8-HR SHIFT

Figure 74. Effect of poor haul roads on tractor efficiency.

(5) *Routing of traffic.* Proper routing of traffic in excavation, haul, and fill areas increases over-all efficiency of the job by preventing interference between the various scrapers and other hauling units.

c. Miscellaneous operations. For proper techniques of using the scraper in the operations of spreading, maintaining slopes, bank sloping, and finishing. (See figs. 76, 77, 78, 79, and 80.)

d. Checking performance. See figure 81 for a check list to be used in determining the efficiency of scraper performance.

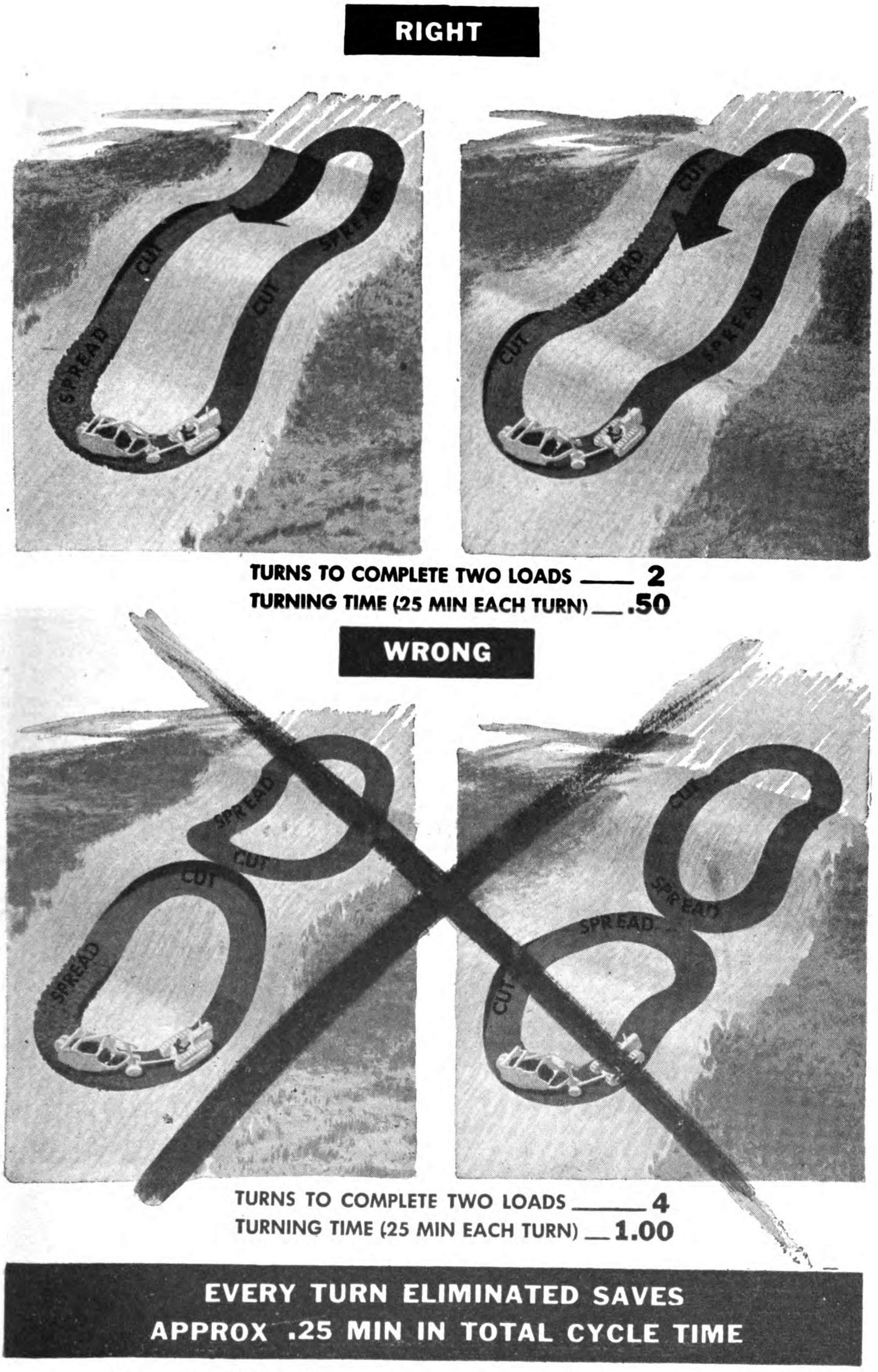
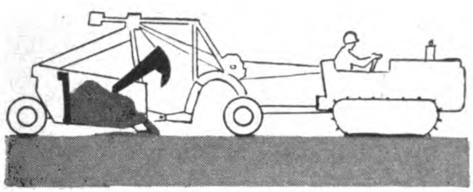
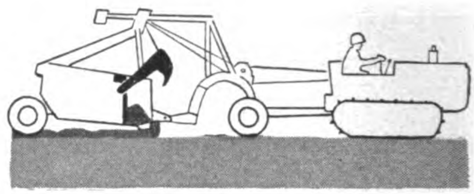


Figure 75. Eliminating unnecessary turns in hauling operations.

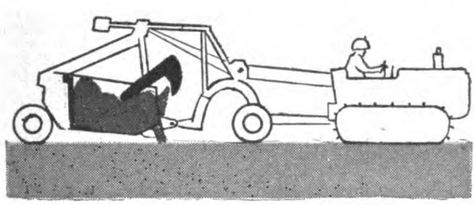
SPREADING AVERAGE DIRT AND SAND

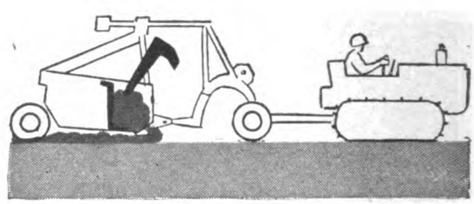




1. SET BLADE HIGH ENOUGH TO ALLOW MATERIAL TO PASS UNDER BLADE
2. RAISE APRON . . . STICKY MATERIAL WILL NOT FALL FROM APRON
3. DO NOT FORCE TAILGATE FORWARD UNTIL MATERIAL IS LOOSENED FROM APRON
4. PULL TAILGATE FORWARD FAST ENOUGH TO EJECT MATERIAL IN STEADY FLOW AND MAINTAIN EVEN DEPTH OF SPREAD
5. BEST SPREADING RESULTS OBTAINED TRAVELING IN 1ST OR 2ND GEAR

EJECTING STICKY MATERIALS

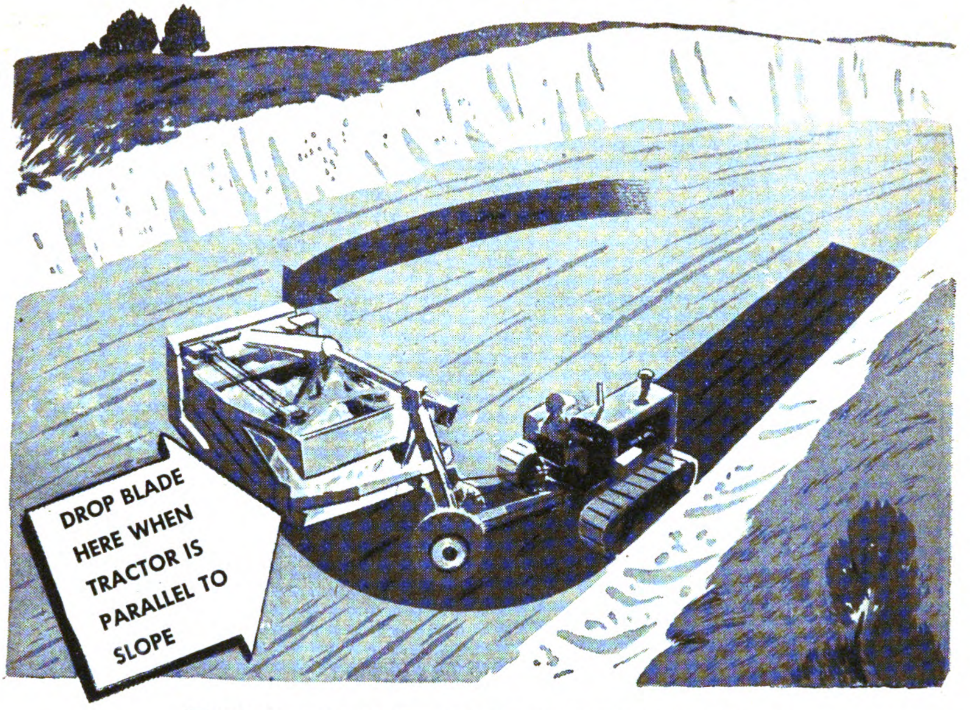




1. SET BLADE FOR REQUIRED DEPTH OF SPREAD, ACCORDING TO TYPE OF MATERIAL USUALLY 6 TO 8 INCHES
2. RAISE APRON, ALLOW EXCESS MATERIAL TO FALL AWAY BEFORE PULLING TAILGATE FORWARD
3. TRAVEL FORWARD DIRT PASSES UNDER BLADE
4. RAISE AND LOWER APRON TO LOOSEN MATERIAL IN FRONT OF BOWL
5. PULL TAILGATE FORWARD AND CONTINUE APRON ACTION
6. SOME MATERIALS CAN BE LOOSENED BY PULLING TAILGATE FORWARD, THEN RETURNING A SHORT DISTANCE

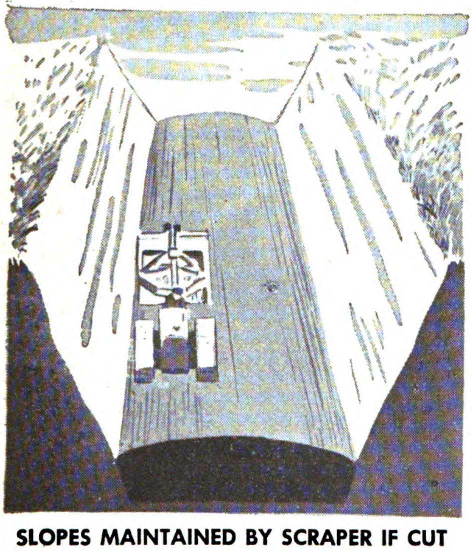
Figure 76. Method of spreading various types of soil.

LOADING TO MAINTAIN SLOPES



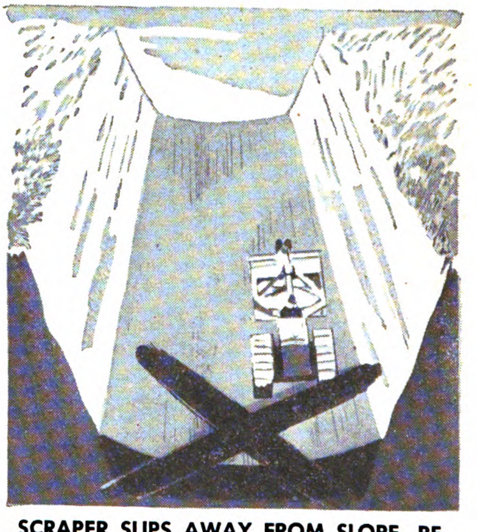
1. TURN FROM CENTER OF CUT TO OUTSIDE SO SCRAPER WILL COME AGAINST SLOPE
2. DROP BLADE AND START DIGGING WHEN TRACTOR IS PARALLEL TO SLOPE
3. THIS WILL CAUSE SCRAPER TO DIG LOWER ON SLOPE SIDE

RIGHT



SLOPES MAINTAINED BY SCRAPER IF CUT PROPERLY

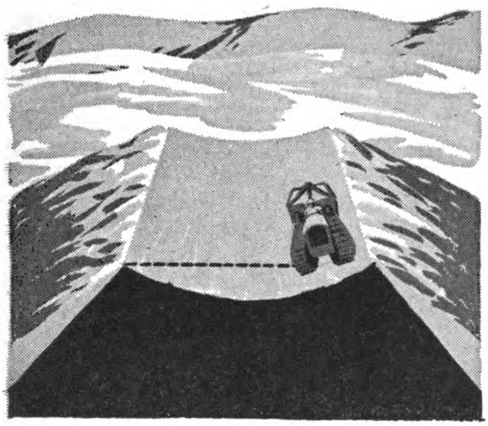
WRONG



SCRAPER SLIPS AWAY FROM SLOPE, RESULTS IN EXTRA WORK

Figure 77. Method of loading to maintain cut slopes.

RIGHT WAY



TO MAINTAIN FILL SLOPE

1. MAKE FILL HIGH ON THE OUTSIDE
2. THIS PREVENTS SCRAPER FROM SLIDING OVER SLOPE
3. ACCURATE SLOPES CAN THUS BE MAINTAINED TO DESIRED HEIGHTS ELIMINATING NECESSITY FOR HANDWORK
4. IF WET CONDITION PREVAILS ARRANGE FOR DRAINAGE TO PREVENT WATER POOLING IN CENTER OF FILL

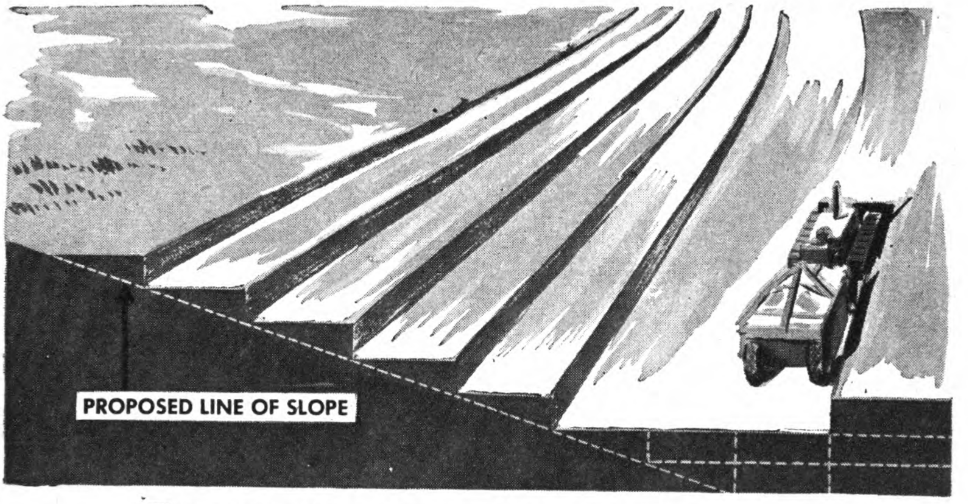
WRONG WAY

RESULT OF INCORRECT METHOD

1. SCRAPER WILL SLIDE OVER SIDE OF HILL
2. DAMAGE TO SLOPE WILL BE CAUSED
3. IMPOSSIBLE TO MAINTAIN ACCURATE DEGREE OF SLOPE, TENDENCY TO WORK AWAY FROM EDGE OF FILL

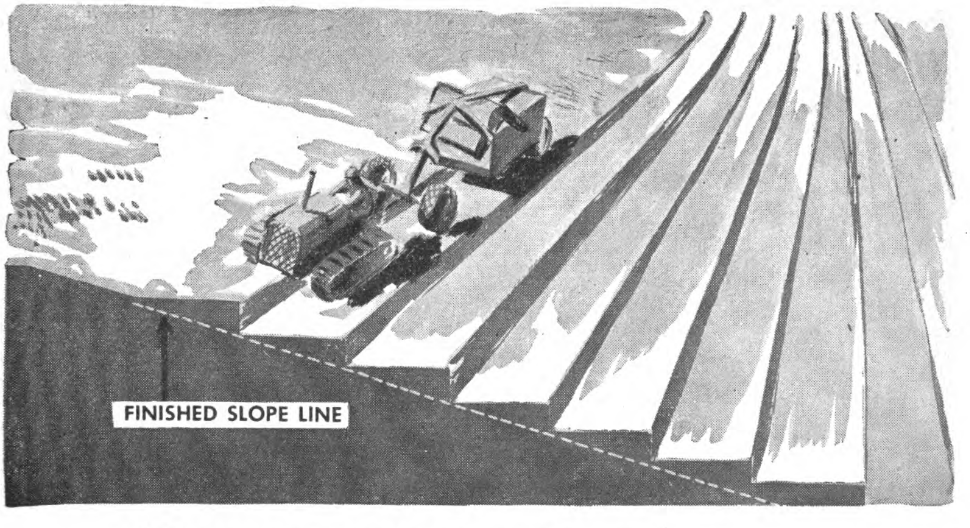
Figure 78. Method of spreading to maintain fill slopes.

METHOD OF CUTTING SLOPES WITH SCRAPER



1. WORK IN LAYERS ACROSS AREA TO BE SLOPED
2. WORK FROM TOP OF SLOPE DOWN
3. AFTER EACH LAYER IS CUT, START NEXT CUT AGAINST SLOPE, ALLOWING BLADE TO CUT TO GRADE
4. STEPS WILL REMAIN TO BE FINISHED BY OTHER METHODS OR EQUIPMENT

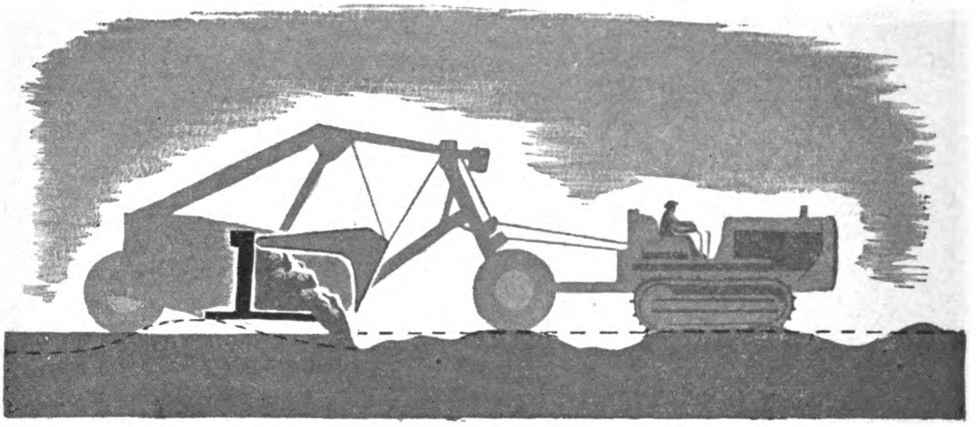
EMERGENCY FINISHING OF SLOPES WITH SCRAPER



1. TO FINISH WITH SCRAPER, STRADDLE EACH STEP
2. START AT TOP OF SLOPE AND WORK DOWN
3. WORK SCRAPER ON PLANE WITH FINISHED SLOPE

Figure 79. Method of cutting and finishing bank slopes with scrapers.

METHOD OF FINISHING TO GRADE WITH SCRAPER BLADE



1 TRAVEL IN LOW GEAR

2 TAILGATE PULLED FORWARD APPROXIMATELY THREE-QUARTERS OF DISTANCE AND HELD IN THAT POSITION

3 BLADE SET TO CUT TO GRADE LINE

4 CUT AND FILL IN FORWARD TRAVEL. AS DIRT IS CUT IT PILES AGAINST TAILGATE AND DRIFTS INTO LOW SPOTS BELOW GRADE LINE

Figure 80. Method of finishing with scraper.

CHECK SCRAPER PERFORMANCE

BY THESE RULES

LOADING

ARE LOADS HEAPED?

IS THE LOAD OBTAINED IN 100 FT. OR LESS?

IS DOWNHILL LOADING MAINTAINED AT ALL TIMES WHEN IT IS POSSIBLE?

ARE LOADS OBTAINED IN THE SHORTEST POSSIBLE TIME—1.0 MIN OR LESS IN AVERAGE CONDITIONS?

WOULD A ROOTER OR PUSHER TRACTOR SPEED LOADING OR YIELD BIGGER LOADS?

HAULING

ARE THE TRACTOR-SCRAPERS AVERAGING 4.0 MPH IN NORMAL CONDITIONS?

ARE TURNS BEING MADE IN ¼ MIN OR LESS?

IS THE OPERATOR USING THE HIGHEST POSSIBLE GEAR?

IS THE OPERATOR TRAVELING OVER THE BEST POSSIBLE ROUTE?

ARE ROADWAYS BEING KEPT SMOOTH TO SPEED TRAVEL?

SPREADING

ARE LOADS BEING SPREAD IN THE HIGHEST POSSIBLE GEAR AND IN AS SHORT A DISTANCE AS IT TAKES TO UNLOAD THE DIRT?

IS SPREADING ACCOMPLISHED IN .5 MIN OR LESS?

IS THE OPERATOR GETTING OFF THE FILL AS QUICKLY AS POSSIBLE?

MECHANICAL

ARE ALL ADJUSTMENTS MAINTAINED?

ARE BLADES OK?

IS CABLE RUNNING FREE?

ARE SHEAVES AND OTHER FRICTION AREAS KEPT THOROUGHLY OILED AND GREASED?

ARE ALL MOVING PARTS WORKING FREELY?

ARE TIRES INFLATED PROPERLY FOR WORK ON HAND?

Figure 81. Check list to determine efficiency of scraper performance.

Section V. POWER SHOVELS, DRAGLINES, CLAMSHELLS, AND CRANES

30. PHYSICAL CHARACTERISTICS. **a.** See table XIV for data on dimensions, weights, and operating capacities of power shovels, draglines, clamshells, and cranes.

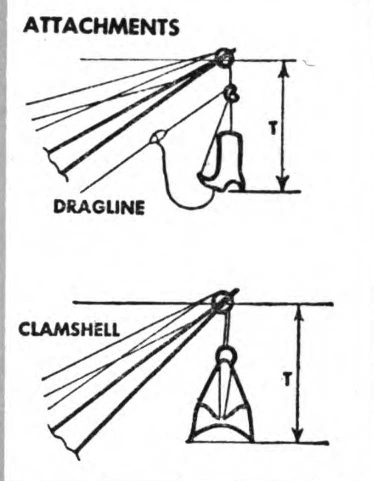
b. The basic unit called a crane is issued as class IV equipment and consists of the cab, power unit, and truck or crawler mounting. The basic unit and attachments necessary to complete it are listed below.

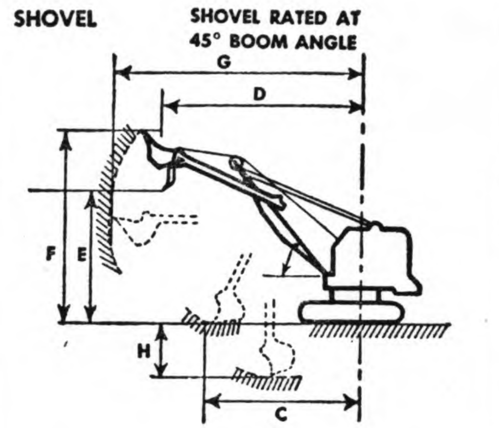
	CRANE: revolving:
	crawler mounted, 3/4 cu.y., 7- to 10-ton, Class III:
	make and model unspecified:
78–2813.003–000	electric driven ... ea.
78–2813.005–000	gasoline driven ... ea.
78–2813.006–000	gasoline electric driven ... ea.
78–2813.008–000	steam driven ... ea.
	make and model unspecified, attachments:
78–2813.009–100	backhoe ... ea.
	boom:
78–2813.009–225	25 ft. ... ea.
78–2813.009–230	30 ft. ... ea.
78–2813.009–235	35 ft. ... ea.
78–2813.009–240	40 ft. ... ea.
78–2813.009–245	45 ft. ... ea.
78–2813.009–250	50 ft. ... ea.
	extension boom end:
78–2813.009–305	5 ft. ... ea.
78–2813.009–310	10 ft. ... ea.
78–2813.009–315	15 ft. ... ea.
78–2813.009–320	20 ft. ... ea.
	extension boom, middle:
78–2813.009–405	5 ft. ... ea.
78–2813.009–410	10 ft. ... ea.
78–2813.009–415	15 ft. ... ea.
78–2813.009–420	20 ft. ... ea.
78–2813.009–500	fairlead ... ea.
78–2813.009–550	gantry ... ea.
	jib:
78–2813.009–605	5 ft. ... ea.
78–2813.009–610	10 ft. ... ea.
78–2813.009–725	pile driver ... ea.
78–2813.009–750	shovel front ... ea.
78–2813.009–800	skimmer ... ea.

(Catalog nomenclature)

Hook blocks, buckets, and other attachments are listed separately as crane attachments. They fit any make of crane. The following sample items are for 3/4-cubic-yard cranes.

nd cranes.



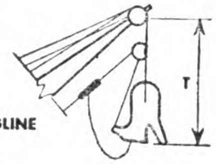


DRAGLINE			CLAMSHELL				RADIUS			HEIGHT				
							CUTTING			CUTTING				
CAPACITY	WEIGHT EMPTY[2]	DUMP CLEAR (T)	CAPACITY	WEIGHT EMPTY[2]	DUMP CLEAR (T)	DIPPER	MAX(G)	AT FLOOR(C)	DUMPING(D)	BANK(F)	DITCH(H)	DUMPING(E)	WORKING WEIGHT
YD	TON	FT	YD	TON	FT	YD	FT	FT	FT	FT	FT	FT	TON
½	0.7	10.0	½	1.2	8.5	½	23.8	16.0	19.0	20.0	5.7	13.8	14.0
½	1.1	9.0	½	1.4	8.3	½	23.5	17.5	20.0	19.5	4.0	14.0	15.0
½	0.6	8.5	½	0.6	8.3	½	23.5	14.0	19.3	24.0	5.5	18.0	11.5
¾	1.5	10.0	¾	1.0	9.8	¾	27.8	17.3	22.7	27.0	7.5	19.2	18.7
¾	0.9	9.5	¾	1.5	8.5	¾	24.8	15.1	20.3	21.1	5.9	15.3	17.0
¾	1.0	10.0	1	1.4	10.5	¾	27.3	17.8	23.1	22.9	6.9	16.6	21.0
¾	1.1	10.5	⅝	1.5	9.5	¾	27.3	16.4	24.4	21.6	7.1	15.0	21.0
1½	1.6	12.9	1½	2.5	12.0	1½	32.0	20.5	27.5	27.3	7.0	18.5	45.0
1½	1.7	11.5	1½	2.2	13.6	1½	33.0	23.3	27.4	28.5	7.1	19.9	47.0
1¼	1.7	11.0	1¼		11.5	1¼	32.1	21.5	28.2		9.0	23.3	35.0
2	2.2	13.6	2	3.2	12.7	2	33.1	22.8	28.0	27.1	8.3	17.5	
1¾		12.5	1¾		12.0	1¾	33.3	21.5	28.0	33.0	8.3	23.9	
2	2.4	13.6	2	3.4	12.7	2	35.2	21.3	30.5	27.8	9.5	18.2	73.0
2½	2.8		2½	3.5		2½	37.5	23.3	31.0	28.8	9.0	19.3	76.0
2½		13.5	2½		9.1	2½	35.5	20.3	29.6	34.5	8.5	24.0	70.0
2¼			2¼			2¼	34.7		28.7	32.8	7.3	22.9	59.4
3		15.0				3	41.0	26.5	35.9		10.5	26.5	105.0
2¾		14.8											

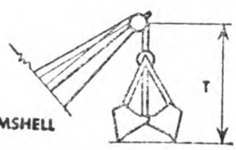
ANE WITH EXTRA COUNTERWEIGHT: OSGOOD 200.........1,100 POUNDS
LIMA 34.........4,000 POUNDS

(Faces p. 88.)

MENTS

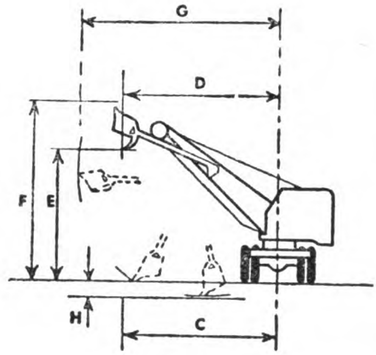


AGLINE



LAMSHELL

SHOVEL



E K[1] UPPORT		DRAGLINE[2]		CLAMSHELL[2]			RADIUS			HEIGHT			
							CUTTING			CUTTING			
K	LOAD	WEIGHT EMPTY	DUMP CLEAR T	WEIGHT EMPTY	DUMP CLEAR T	DIPPER	MAX G	AT FLOOR C	DUMPING D	BANK F	DITCH H	DUMPING E	WORKING WEIGHT
FT	TON	TON	FT	TON	FT	YD	FT	FT	FT	FT	FT	FT	TON
33	1.4	0.5	8.3	0.8	6.8	⅜	20.0	13.0	16.8	16.5	3.5	10.9	13.5
33	1.4												
31	1.5	0.5	8.3	0.8	6.8	⅜	20.0	13.0	16.8	17.0	2.9	11.5	17.5
31	1.5												
35	1.5	0.9	10.0			¾	24.2	15.4	20.8	21.2	5.2	15.5	22.0
36	1.4												
33	2.2												
35	2.3					¾	24.2	15.4	20.8	21.2	5.2	15.5	22.0
36	1.8												
33	3.4												
		0.9	10.8	1.5	9.8	¾	26.2	15.5	21.7	21.5	6.0	14.7	26.0
36	2.0												
33	3.2												

D CHAINS.
N.

(Faces p. 88.)

CRANE ATTACHMENTS:

......	......	......
......	......	......
78–2940.110–075	Bucket, clamshell, ¾ cu. yd.	ea.
......	......	......
......	......	......
......	......	......
78–2940.130–075	Bucket, dragline, ¾ cu. yd.	ea.
......	......	......
......	......	......
......	......	......
78–2940.400–010	Hook block, 10 ton	ea.
......	......	......
......	......	......
......	......	......

(Catalog nomenclature)

Note: All catalog numbers listed here are used as examples and are subject to change.

Table XIV. Cont'd. Estimated fuel and lubricating-oil consumption

Machine capacity (cu. yd.)	Fuel consumption per hour[1]		Lubricating-oil consumption per hour[2]	
	US Gallons	Liters	US Gallons	Liters
Diesel engine				
½	1.6–1.9	6.0–7.2	0.07	0.26
¾	2.4–2.9	9.0–11.0	0.10	0.38
1	3.1–3.8	11.7–14.3	0.10	0.38
1¼	3.7–4.5	14.0–17.0	0.16	0.61
1½	4.6–5.5	17.4–20.8	0.18	0.68
2	5.8–7.0	22.0–25.5	0.24	0.91
2½	7.0–8.5	26.4–32.1	0.26	1.00
Gasoline engine				
½	3.0–3.7	11.3–14.0	0.05	0.19
¾	4.0–5.0	15.0–19.0	0.07	0.26
1	5.5–6.7	20.8–25.3	0.09	0.34
1¼	6.5–8.0	24.6–30.0	0.12	0.45
1½	7.5–9.0	28.4–34.0	0.14	0.53
2	9.5–11.5	36.0–43.5	0.17	0.65

[1] Fuel consumption for operation in normal altitudes.
[2] Lubricating-oil consumption based on a complete oil change every 70 hours with oil added during operations.

Table XV. Uses of shovels and cranes with attachments

Operation	Shovel	Dragline	Clamshell	Lifting crane	Trench hoe
General excavating	Excellent	Excellent	Suitable	--------	--------
Stripping	Suitable on rough grades	Excellent	Suitable	--------	Expedient
Pioneering	Excellent	Suitable	Excellent	--------	Expedient
Short-haul excavating	Excellent (with trucks)	Suitable (with trucks)	Excellent (with trucks)	--------	Suitable (with trucks)
Long-haul excavating	Excellent (with trucks)	Suitable (with trucks)	Excellent (with trucks)	--------	Suitable (with trucks)
Sloping	Expedient	Expedient	Expedient	--------	Expedient
Backfilling	Expedient	Suitable	Suitable	--------	Expedient
Rooting and scarifying	Expedient	--------	--------	--------	Expedient
Lifting	Expedient (using a sling)	Expedient (using a sling)	Expedient (using a sling)	Excellent	Expedient (using a sling)
Clearing	Expedient	--------	Expedient	Expedient	--------
Winching	--------	Expedient	Expedient	Expedient	--------
Breaking pavement	--------	--------	--------	Suitable (raising and dropping block)	--------
Loading (hoppers, etc.)	--------	Expedient	Excellent	--------	--------
Trenching	Suitable (difficult to control)	Suitable (difficult to control)	Suitable	--------	Excellent

***Note.*—*Excellent*—Efficient use of equipment.**
Suitable—Can be used if a more suitable type of equipment is not available.
***Expedient*—Inefficient if used continually. Use only when other equipment is not available or the length of operation does not warrant brin ing in a better machine.**

To order a machine for a certain job, the basic unit with power-type specified must be ordered with the attachments. Each attachment needed must be listed separately. The necessary cable for the machine ordered is furnished with the basic unit.

31. USE OF SHOVELS, DRAGLINES, CLAMSHELLS, AND CRANES.

a. Use. Table XV lists uses of cranes with various attachments. It should be noted that although the machines can perform all the operations listed, they are used as expedients only in some of the operations.

b. Controlling factors. The type and size of machine used for a particular operation are controlled by the following factors:

(1) Area of project and quantity of earth to be moved.
(2) Moisture content and size of material particles.
(3) Depth of excavation.
(4) Hauling methods and type and size of hauling units.
(5) Distance trucks must carry excavated material. (Shovels are best where hauls are 3,000 feet or more.)

32. ESTIMATE OF WORK OUTPUT.

a. Work output formula. The following formula is used to estimate shovel output in cubic yards per hour:

$$\text{OUTPUT} = \frac{3{,}600 \times Q \times f \times E \times K}{Cm}$$

Where 3,600 = seconds per hour.
Q = rated dipper, clamshell, or dragline bucket capacity in cubic yards.
f = soil conversion factor.
E = shovel efficiency factor.
K = bucket or dipper efficiency factor.
Cm = total cycle time in seconds.

(1) *Rated capacity (Q).* Rated shovel, dipper, dragline, or clamshell bucket capacity is expressed as *struck capacity,* the cubic yards of earth the dipper or bucket holds when it is filled level.

(2) *Soil conversion factor (f).* Bucket or dipper capacity is expressed in terms of loose yards. To determine in-place yards or compacted yards excavated, apply the proper soil conversion factor (f) from table II.

(3) *Shovel efficiency factor (E).* The shovel efficiency factor takes into account the fact that a full 60-minute work-hour is rarely attained. Output time is lost moving the machine in work, shifting the boom up or down, making lubrication checks, refueling, and allowing short breaks for the operator. Experience shows that with skillful operators an average E value of 0.80 can be used but it must be checked on each job for each operator.

(4) *Bucket or dipper efficiency (k).* Factor (k) makes allowance for the different bucket or dipper capacities (Q) in various types and conditions of soil. Table XVI lists the approximate factors used for preliminary estimates. Factors (k) should be checked and revised as the job proceeds.

Table XVI. Bucket or dipper efficiency factor (k)

Easy digging	Medium digging	Medium-hard digging	Hard digging
Shovel-dipper factor 95% to 100%	Shovel-dipper factor 85% to 90%	Shovel-dipper factor 70% to 80%	Shovel-dipper factor 50% to 70%
Dragline bucket fac or 95% to 100%	Dragline-bucket factor 80% to 90%	Dragline-bucket factor 65% to 75%	Dragline-bucket factor 40% to 65%
Loose, soft, free running materials Close-lying materials which fill dipper or bucket full and frequently provide heaped load Overload compensates for swell of material	Harder materials that do not require blasting, but break up with bulkiness, causing voids in dipper or bucket	Materials requiring some breaking up by light blasting or shaking, but bulky and somewhat hard to penetrate, causing voids in dipper or bucket	Blasted rock, hard pan, and other bulky materials which are difficult to penetrate and leave large voids in dipper or bucket
Dry sand or small gravel Moist sand or small gravel Loose earth Muck Sandy clay Cinders or ashes Well-blasted material	Dry or wet clay Coarse gravel Packed earth	Well-broken limestone, sand rock, and other blasted rocks Blasted shale Heavy, wet, sticky clay Gravel with large boulders Heavy, wet gumbo Cemented gravel	Hard tough shale Limestone Trap rock Granite Sandstone Conglomerate Caliche rock (All above blasted to large pieces mixed with fines and dirt) Tough rubbery clay that shaves from bank

Conditions: Digging face long enough to allow dipper or bucket to obtain load as given. **Allowance must be made for smaller loads when digging in shallow banks, especially with large capacity dippers or buckets. Figures are only approximate.**

(5) *Cycle time (Cm).* (*a*) The following operations make up the working cycle.

1. Digging.
2. Swinging to dump.
3. Dumping.
4. Swinging to dig.

(*b*) Cycles for shovels, clamshells, and draglines are diagrammed in figure 82. Cycle-time ranges for various shovels are listed in table XVII.

Table XVII. Cycle time for shovels (Cm)

Capacity (cu. yd.)		Cycle time (seconds)[1]		
		Easy digging	Medium digging	Hard digging
Shovel (90° swing)	½	15	18	24
	¾	18	20	26
	1	18	20	26
	1¼	18	20	26
	1½	18	20	26
	2	18	20	26
	2½	20	22	28
	3	22	24	30
	4	24	26	32
Dragline (110° swing)	½	20	24	30
	¾	22	26	32
	1	24	28	35
	1¼	24	28	35
	1½	24	28	35
	2	28	33	40
	2½	28	34	41
	3	30	35	42
	4	32	38	45

[1] For each increase of 10° in swing, add 2 seconds to cycle time; for each decrease of 10°, subtract 2 seconds from cycle time.

Figure 82. Shovel, clamshell, ana aragline cycles.

Figure 82—Continued.

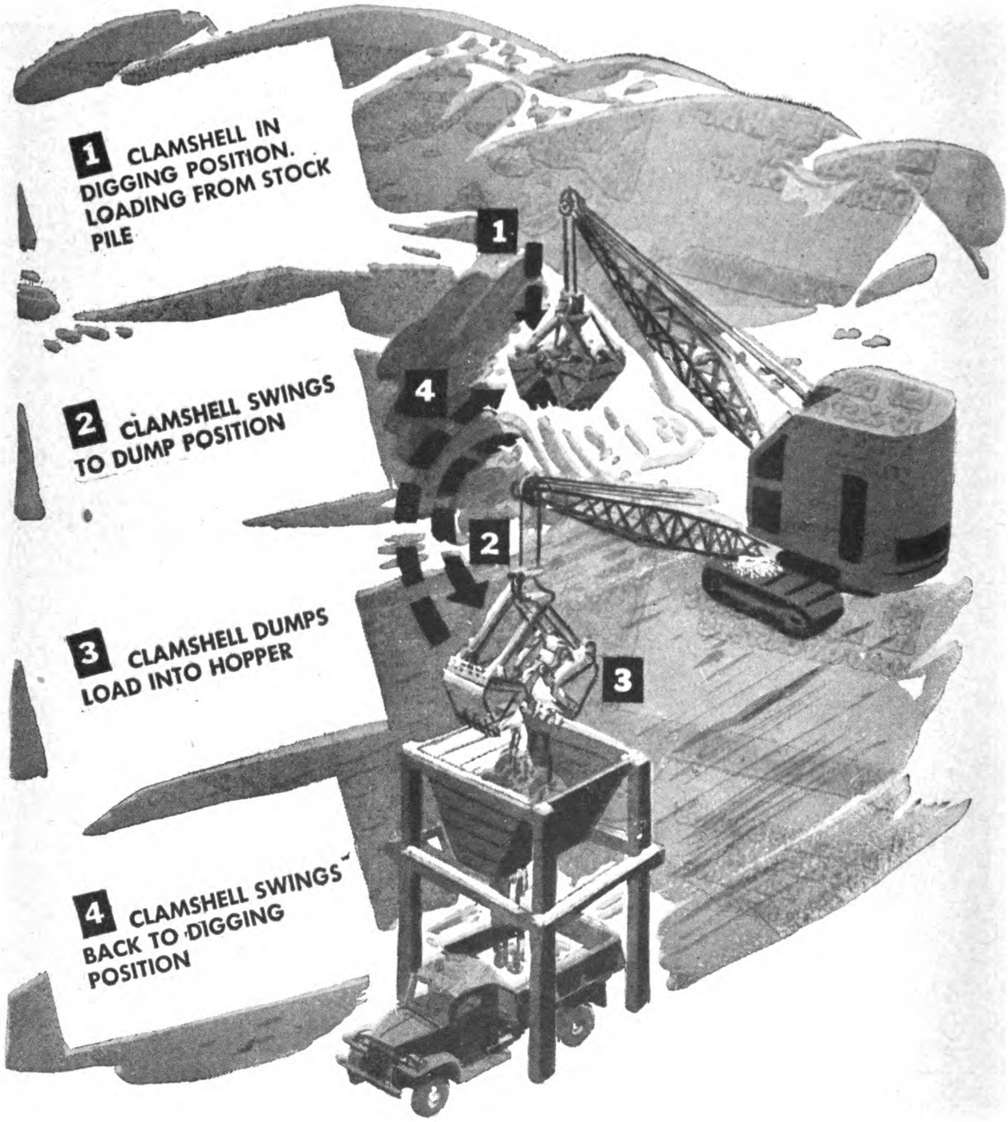


Figure 82—Continued.

b. Tables of estimated work output. Table XVIII gives the estimated work output in cubic yards per hour for shovels and draglines. These yardages can be obtained only when all conditions are favorable and experienced operators are used.

Table XVIII. Estimated shovel and dragline output

Capacity (cu. yd.)		Theoretical maximum output $k = 1.00$ 100% efficiency (cu. yd.)	Estimated output under average conditions (Cu. yd. per 50-min. hr.)		
			Easy digging	Medium digging	Hard digging
			$k = 0.90$	$k = 0.85$	$k = 0.70$
Shovel (90° swing)	½	100	85–95	70	35–45
	¾	135	105–120	95	55–65
	1	180	140–160	125	70–85
	1¼	225	180–200	160	90–105
	1½	270	215–240	190	110–125
	2	360	290–320	250	145–165
	2½	410	320–360	290	170–190
	3	450	350–390	320	190–210
	4	545	410–450	385	220–240
Dragline (110° swing)	½	75	60–70	50	25–35
	¾	105	85–100	70	35–45
	1	130	105–120	85	50–60
	1¼	160	135–150	105	60–70
	1½	190	160–180	125	75–85
	2	220	185–210	145	85–100
	2½	265	225–255	175	105–120
	3	310	255–290	205	125–145
	4	380	300–350	250	150–170

33. SUPERVISION FOR MAXIMUM WORK OUTPUT. Supervisors responsible for obtaining maximum shovel, dragline, clamshell, and crane efficiency should keep the following considerations in mind.

a. Shovels. (1) *General.* Shovels are best for general excavation against a high working face. All material should be well broken up, and rocks and boulders must be small enough to pass through the dipper. The shovel should be kept as level as possible. When used on soft material, the crawlers should be supported on construction mats.

(2) *Digging.* Digging starts with the bucket at crawler lever 2 or 3 feet in front of the crawlers. The dipper is filled with a straight, forward movement. Shovels operate most efficiently against a face at least 5 feet high. This permits a thin cut to fill the dipper and avoids a heavy, deep, slow, short cut. When using shovels for deep excavations, the face of the excavation should be terraced (fig. 83). If one pass does not fill the dipper in sticky or hard material, output is increased by making a second pass before swinging and dumping.

Example: A full shovel cycle with one pass takes 30 seconds in hard material and digs six-tenths of a dipper full. A second pass will increase the dipper load to nine-tenths of a dipper full with a 6-second time increase. The dipper capacity is increased 50% with a 20% increase in time; a total capacity increase of 25% in a 50-minute working hour.

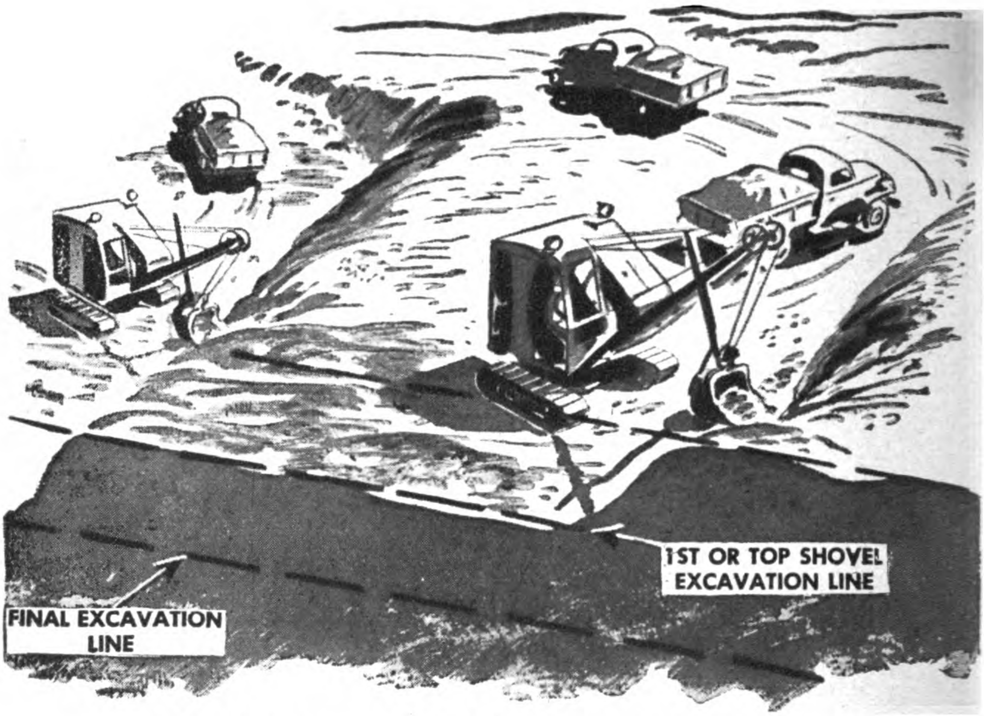


Figure 83. Terracing banks or high faces with shovels.

(3) *Swing.* Swing to and from the working face should be as short as possible. Swing can be cut to a minimum by spotting trucks carefully and close to the working face. Experienced operators combine swing and dump to save time. Digging and swing are *not* combined because it puts excessive strain on the dipper stick and boom.

(4) *Dumping.* The load is usually dumped into a stock pile or truck while the shovel is swinging.

(5) *Hauling.* Trucks are spotted close to the face and, whenever possible, on each side of the shovel. (See fig. 84.) The number of trucks required varies with length of haul, shovel capacity, truck capacity, and type of condition of material being excavated. *The shovel*

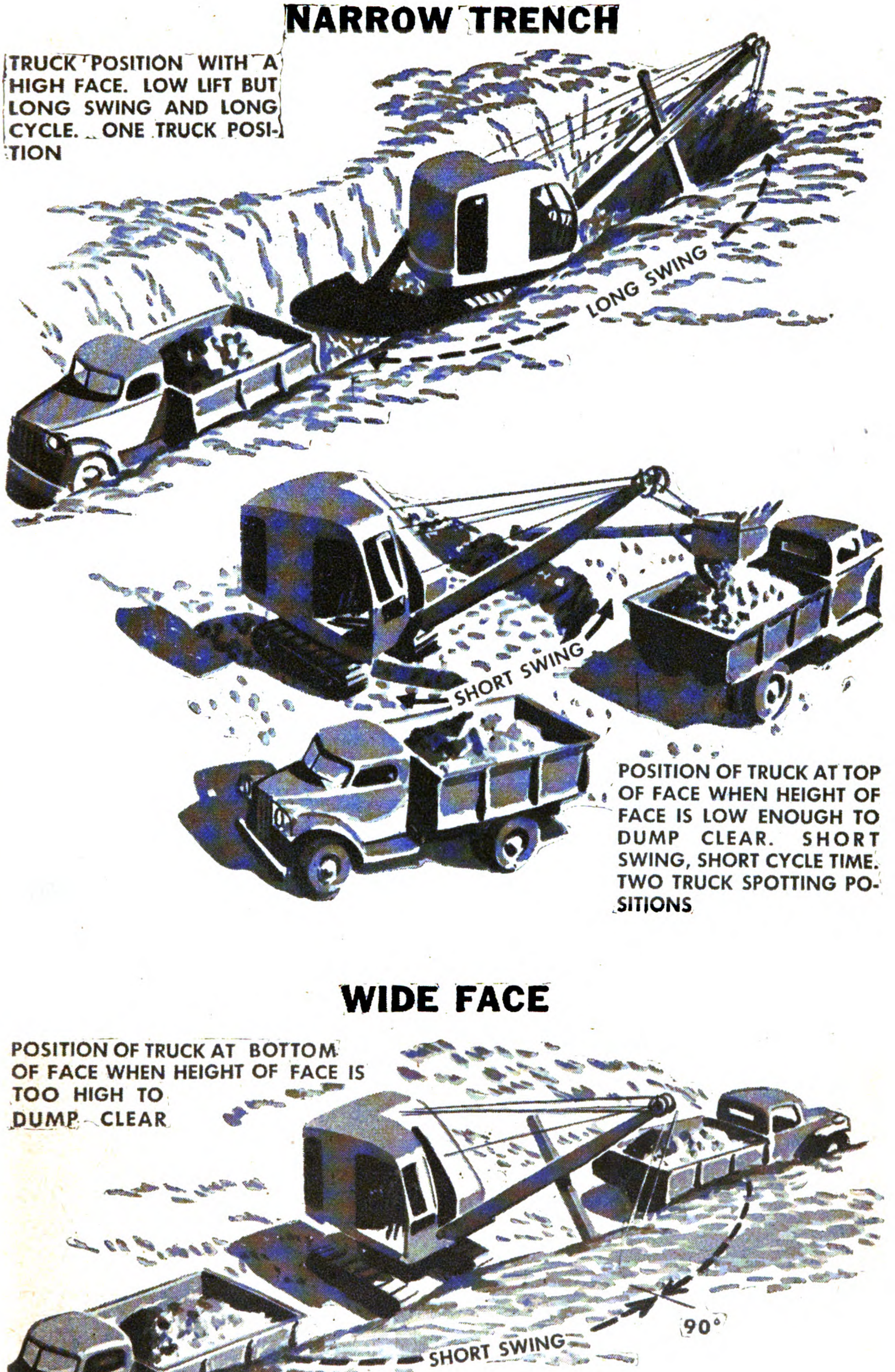


Figure 84. Spotting trucks.

should never be kept waiting for trucks. The following formula is used to estimate the number of trucks required to keep a shovel in operation at highest capacity:

$$N = 1 + \frac{60\left[\left(\frac{d}{v_1}\right) + T_1 + \left(\frac{d}{v_2}\right) + T_2\right]}{nCm}$$

Where, N = number of trucks.
n = number of cycles required to fill a truck.
60 = seconds per minute.
d = length of haul in feet.
V_1 = speed of loaded truck in feet per minute (speed in miles per hour times 88).
T_1 = time required to dump truck (minutes).
V_2 = speed of unloaded truck in feet per minute.
T_2 = time in minutes required to spot truck under shovel.
Cm = cycle time in seconds.

This formula can be used in *preliminary estimates.* After the job has started, the job supervisor can change the number of trucks to keep shovel and trucks operating at highest efficiency.

(6) *Auxiliary equipment.* Dozers are used to pile up material for the shovel. They are also used to knock down tall banks to avoid undercutting (fig. 85).

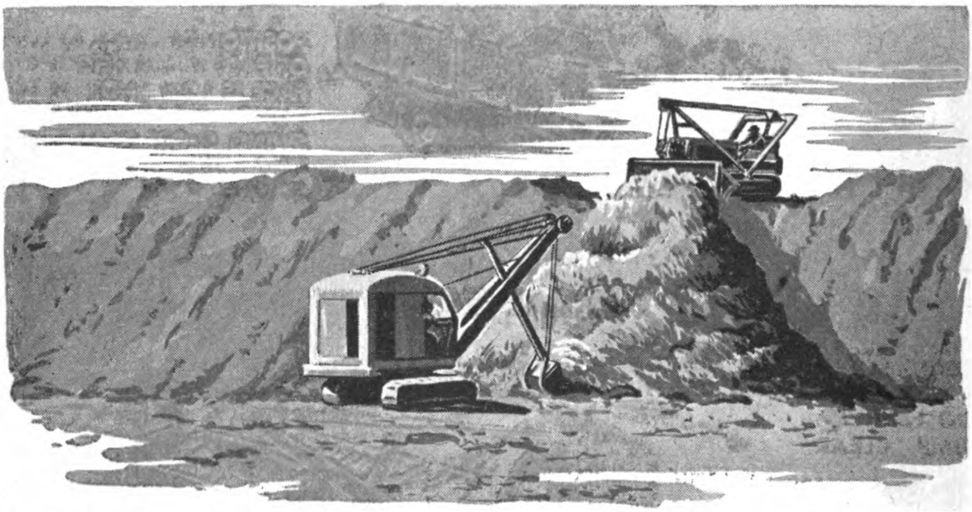


Figure 85. Dozer knocking down upper edge of high bank to prevent shovel undercutting face. (See also fig. 181.)

b. Draglines. (1) *General.* Draglines are best used to excavate loose materials below the working level of the machine and can be used in underwater excavation. When a long reach can be made in no other way, the machine can be tilted slightly after boom has been lowered as far as possible (fig. 86).

(2) *Digging.* Digging is started with the bucket at the base or deepest point of the excavation (fig. 87) and pulled in a straight line toward

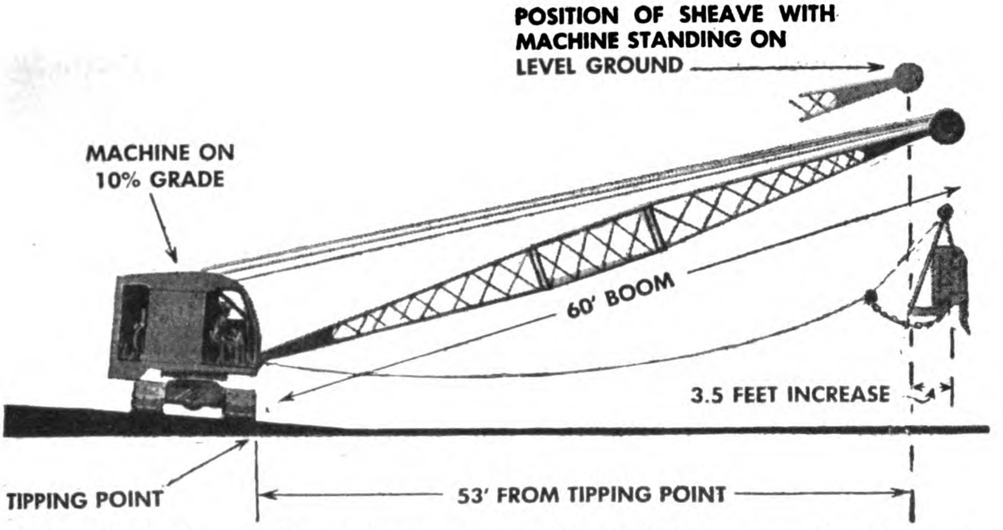


Figure 86. Tilting dragline to increase reach. Only skilled operators should use this technique.

the machine until the bucket is full. If the boom is allowed to swing while digging, it will be overstressed and may buckle.

(3) *Swing.* The bucket is hoisted and swung to the dump point. Hoisting and swinging should be kept to a minimum.

(4) *Dumping.* Because dragline buckets are difficult to dump accurately, they are normally used in side-casting and stock-piling. When the load must be dumped in a truck or hopper, dumping time is doubled. (See table XVII.)

(5) *Return swing, throw, and lowering.* The return swing starts immediately after dumping and is carried through to the throw (fig. 87). Depending on the operator's skill, the throw is one-third to two-thirds the clear dump height. The bucket is lowered as it is thrown.

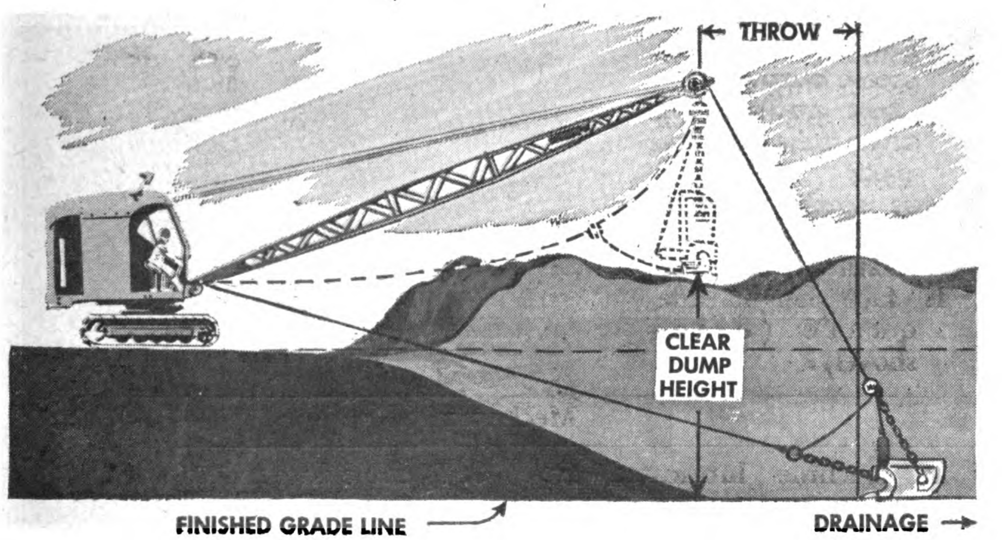


Figure 87. Dragline throw.

c. Clamshell. (1) *General.* Clamshells are best used in underwater excavation, hopper work, and in controlled excavation such as culvert trenches and footings.

(2) *Digging.* In hard material, teeth are attached to the bucket jaws to facilitate digging. The teeth are removed when unloading cars or handling loose material in hopper work. This prevents damaging car floors and hopper sides and permits complete car-floor clearing.

(3) *Hoist and swing.* Hoist and swing to the dump position are done in one motion. To prevent the bucket hitting the boom, the boom should never be raised at an angle over 60°.

(4) *Tagline.* The tagline is used to hold the bucket in line with the machine and keep the lines from twisting and fouling. It must be used at all times

(5) *Controlled excavation.* A man is used as "bucket spotter" in controlled excavation. The operator holds the bucket a few inches above the ground, dropping it on signal after the spotter positions the bucket.

d. Lifting crane. Cranes and shovels can be converted to lifting cranes and used in clearing work, lifting, and winching.

e. Trench hoe. Some shovels can be converted to trench hoes, often called drag shovels or back hoes.

f. Checking performance. Performance should be checked and yardage-time calculations kept on each job. A sample check list to determine operating efficiency is shown below.

Check performance by the following rules

Digging	Swinging	Dumping
1. Is bucket or dipper full?	1. Is swing as short as possible?	1. If dumping into trucks, is spillage reduced to a minimum?
2. Are loads obtained by a short, fast swing?	2. Are swing and dump combined in one motion?	2. Is dump height as low as possible?
3. Would blasting speed loading and increase output?		3. Does all the material leave the bucket?
4. Is best available attachment being used?		4. Are hauling facilities adequate?
5. Are teeth necessary in digging?		
6. Is drainage complete?		
7. Is face height adequate (using shovel)?		

Mechanical	
1. Is machine lubricated frequently?	3. Is cable in good condition? (All except dragline cables, should be lubricated.)
2. Are all attachments in good condition?	

4. Are all sheaves, undercarriage pinions, and dipper-stick racks and pinions lubricated with heavy grease?

5. Are crawlers in good working condition?

6. Are controls and clutch and brake linings in good shape?

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g. Drainage. All cuts are made so rain and ground water will drain readily. Whenever possible, cutting starts at the lowest point and the floor of the excavation is sloped (fig. 88). Where drainage ditches are used, they are excavated roughly as the cut proceeds.

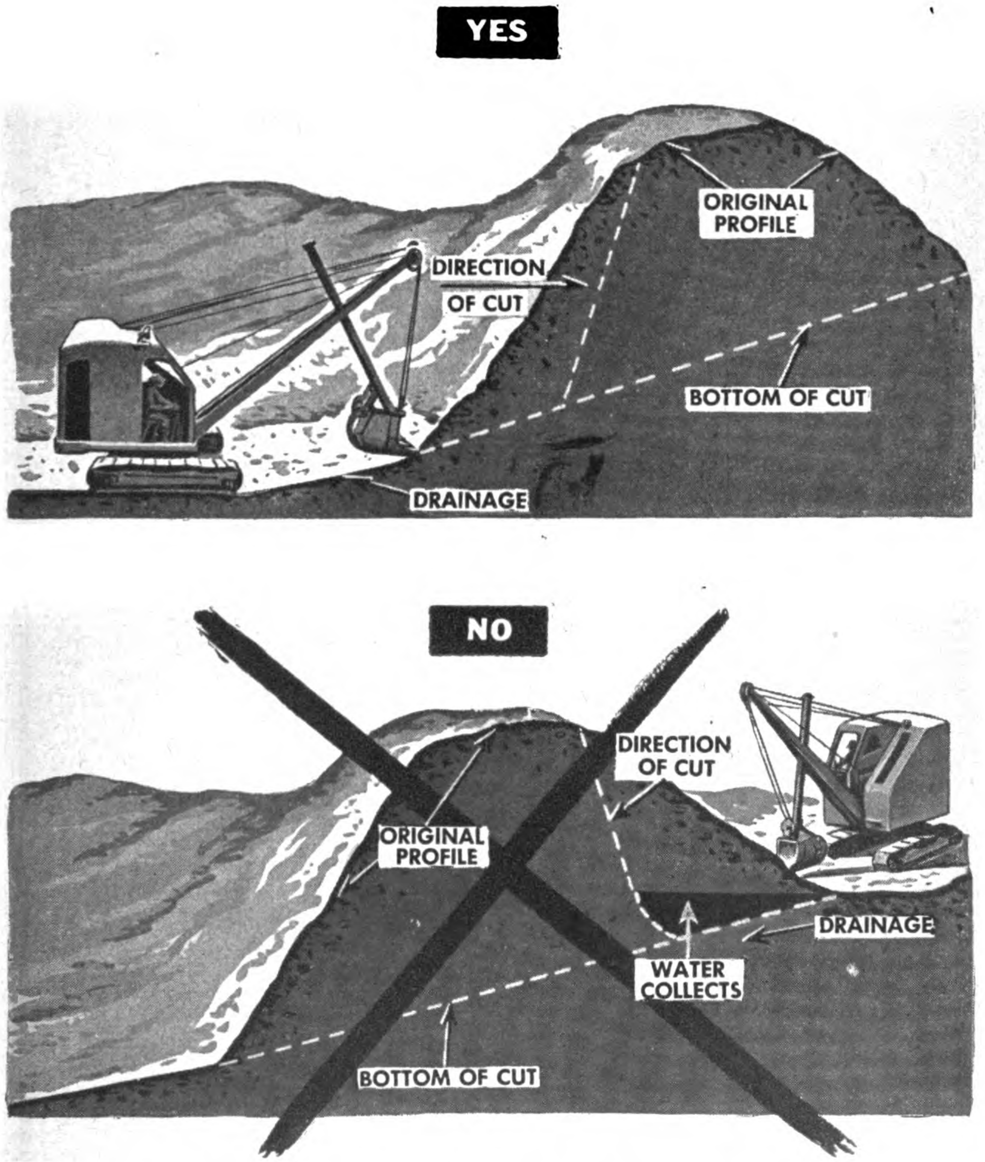


Figure 88. Correct method of cutting to get proper drainage.

34. PHYSICAL CHARACTERISTICS OF DUMP TRUCKS. See table XIX for data on dimensions, weights, and operating capacity of dump trucks.

35. ISSUE OF DUMP TRUCKS. Dump trucks are issued as organic equipment to most engineer units. Additional dump trucks can be obtained from dump truck companies (T/O & E 5–88). Cargo trucks, also organic equipment of most engineer units, can be used as expedients when dump trucks are not available. Cargo trucks are also available from quartermaster truck companies (T/O & E 10–57).

36. USE OF DUMP TRUCKS. a. Primary use. Dump trucks are used to:

(1) Receive, haul, and dump cleared materials, such as trees, stumps, undergrowth, and boulders.

(2) Receive, haul, dump, and help spread excavated materials from shovels or cranes.

(3) Receive, haul, dump, and help spread base-course and surfacing materials.

(4) Receive, haul, dump, and help spread bituminous material.

(5) Receive, haul, dump, and help spread concrete. (This is not a recommended practice but may be necessary when using a fixed mixing plant.) The following precautions should be taken:

(*a*) Make haul as short and fast as possible.

(*b*) Use a rich mix.

(*c*) Hand-mix concrete by shoveling when it is dumped. The mix segregates during hauling and should be thoroughly vibrated when placed.

b. Expedient use. Expedient use of cargo trucks adapted to dump-truck work is described in paragraph 73.

37. ESTIMATE OF TRUCK OUTPUT. a. Capacities. The struck and heaped capacities of dump-truck bodies are listed in table XIX and illustrated in figure 89.

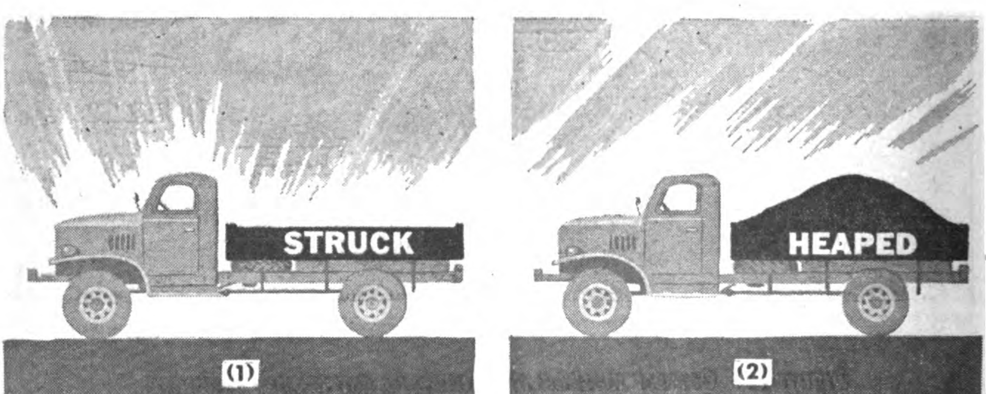
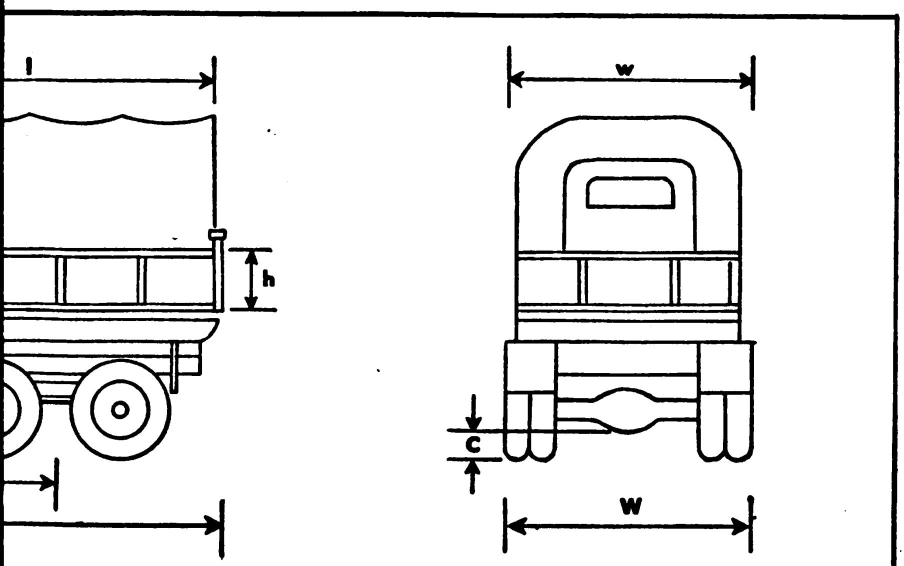


Figure 89. ① Struck capacity of dump truck. ② Heaped capacity of dump truck.

	PERFORMANCE			MISCELLANEOUS			
…PTH	TURNING RADIUS	FORDING DEPTH [1]	FUEL CONSUMPTION (AVERAGE CONDITION)	CYLINDERS	BRAKE HORSEPOWER	ELECTRICAL SYSTEM	IGNITION TYPE
…HES	FEET	INCHES	MILES PER GALLON	—	—	VOLTS	—
…OT …EN	26.0	32	9	6	90	6	BATTERY
…OT …EN	29.5	32	9	6	83	6	BATTERY
…4	27.5	26	9	6	88	6	BATTERY
…0	37.0 [6] 37.5 [7]	24	7.5	6	104	6	BATTERY
…OT …EN	35.0 [6] 36.5 [7]	24	3	6	119	6	BATTERY
…OT …EN	29.0	32½	5½	6	130	6	BATTERY



(1) *Struck capacity* is the number of loose cubic yards of material the dump body will hold when filled level.

(2) *Heaped capacity* is the number of loose cubic yards of material the dump body will hold when heaped.

b. Number of trucks required. The number of trucks required for any operation depends on loading time, length of haul, haul and return time, and dumping time. A formula for the number of trucks required to keep a shovel operating at top efficiency is given in paragraph 33a (5). Formulas for expedient methods of truck loading can be set up in the same form.

38. SUPERVISION FOR MAXIMUM WORK OUTPUT. The supervisors responsible for obtaining maximum truck efficiency should keep the following considerations in mind.

a. Fill dump body to a heaping load whenever possible. When haul roads are in poor condition and fill material is wet, trucks should not be filled to heaped capacity. The deadlined equipment resulting from broken springs, axles, and transmissions under these conditions more than offsets the gain in production from maximum loads.

b. Keep dump body clean and in good condition.

c. Place heaviest portion of rock loads in rear end of dump body to minimize weight on dumping mechanism.

d. Before loading concrete, spray walls and sides of dump body with water to prevent concrete from sticking. Thoroughly clean and spray dump body with water before each succeeding load of concrete.

e. Use a spotting log or block where trucks back into loading or dump position (fig. 90).

Figure 90. Spotting log to place truck for shovel loading.

f. Operate at highest safe speed in highest possible gear during haul.

g. Whenever possible use two haul roads: one leading to the dump, the other away from it. Keep grades on haul roads to a minimum.

h. Lay out loading and dumping points so backing and passing are minimized.

i. When dumping material that requires spreading by a bulldozer, move truck forward as the load is dumped (fig. 91). This minimizes the bulldozer's spreading job.

39. BOTTOM-DUMP DIRT OR ROCK WAGON. a. Physical characteristics. See table XX for data on capacity, weights, dimensions, and operating characteristics of bottom-dump dirt or rock wagon.

b. Use of wagons. The bottom-dump dirt or rock wagon is a heavy-duty hauling unit designed for use with a crawler-mounted tractor of not less than 50 hp. Crawler-mounted dirt wagons are designed for use on terrain not suitable for rubber-tired equipment.

c. Supervision for efficient use. Supervisors responsible for obtaining maximum dirt-wagon efficiency should keep the following considerations in mind.

(1) *Maintenance.* Preventive maintenance and first echelon repair must be performed thoroughly each day. Follow the proper maintenance manuals and charts.

Table XX. Capacity, weights, dimensions, and operating data for bottom-dump dirt or rock wagon

Designation	Wagon, dirt or rock, crawler-mounted, bottom-dump	
Rating Towing speed	13-cubic-yard 1.5 mph	
Dimensions:		
Over-all—		
Length	21′1″	
Width	10′	
Height	6′9″	
Ground clearance	30½″	
Inside dump body:		
Length	13′6″	
Width	7′	
Depth	4′1″	
Doors:		
Length	12′	
Width of opening	4′4″	
Weight:		
Empty	16,700 lb	
Loaded	48,000 lb	
Shipping:		
Uncrated	16,500 lb	
Crated (2 boxes)	17,072 lb	
Cubage	17.5 ship tons	
	Working conditions	
	Poor	Excellent
Rated performance[1]		
Cu yd per 60-min hr	80	96
Cu yd per 50-min hr	67	80

[1] 1,000-foot haul distance.

Figure 91. Truck spreading fill material.

(2) *Operation.* (*a*) Keep the dump body clean and free of dirt.

(*b*) Wherever possible, lay out loading and unloading points so wagons do not have to do any backing. One continuous route with only one stop for loading is best.

(*c*) Have loaded haul route run downhill.

(*d*) Keep haul route well cleared and smooth.

40. BOTTOM-DUMP DIRT OR ROCK TRAILER (fig. 92). a. Physical characteristics. See table XXI for data on capacity, weight, dimensions, and operating characteristics of bottom-dump dirt or rock trailer.

Figure 92. Bottom-dump dirt or rock trailer.

Table XXI. Capacity, weights, dimensions, and operating data for bottom-dump dirt or rock trailers

Capacity (loose cubic yards):	
Struck	11.5 cu yd
Heaped	17.0 cu yd
Bowl dimensions:	
Width:	
Top	8 ft
Bottom	5 ft
Length;	
Top	12.6 ft
Bottom	7.9 ft
Height	5 ft
Maximum discharge area	35 sq ft
Over-all dimensions, with Tournapull:	
Length	30.1 ft
Width	10.5 ft
Height	9.0 ft
Ground clearance	19 inches
Outside turning radius	19.5 ft
Towing speed, with Tournapull	14 mph
Brakes	Hydraulic
Dump-bottom control	Double cable
Shipping weight	13,500 lb

b. Use of trailers. The bottom-dump dirt or rock trailer is designed for use with Tournapull Super C power unit. It is used to haul large quantities of earth medium distances of 1,500 feet to approximately 3 miles over prepared haul roads.

c. Supervision for efficient use. Supervisors responsible for obtaining maximum dirt-trailer efficiency should keep the following considerations in mind.

(1) *Maintenance.* Preventive maintenance and first echelon repair must be performed thoroughly each day. Follow the maintenance manual and lubrication charts.

(2) *Operation. (a)* Keep dump body clean.

(b) Wherever possible, lay out loading and unloading points so trailers do not have to back. One continuous route with only one stop for loading is best.

(c) Have loaded haul route run downhill.

(d) Keep haul route well cleared and smooth.

41. EQUIPMENT TRAILERS. a. Physical characteristics. See table XXII for data on capacity, dimensions, weights, and operating characteristics of equipment trailers.

b. Use. Equipment trailers are used for rapid transportation of heavy construction equipment such as shovels, concrete mixers, scrapers, dozers, and trailer-mounted air compressors. In general, they are ef-

Table XXII. *Capacity, weight, dimensions, and operating data for equipment trailers*

BODY TYPE	CAPACITY	WEIGHTS			DIMENSIONS						OPERATION DATA			
		NET	PAYLOAD	GROSS	LENGTH (L)	WIDTH (W)	HEIGHT (H)	LOADING HEIGHT (h)	GROUND CLEARANCE (c)	SHIPPING DIMENSIONS	TIRES		BRAKES	TOWING
	TONS	LB	LB	LB	FT	FT	FT	IN	IN	CU FT	OPERATING	SPARE		TRACTOR (TRUCKS)
TRAILER, FULL, FLAT BED	8	9,900	16,000	25,990	25.0	7.4	4.7	39	10	665 [2] 825 [3]	8	1	AIR	2½-TON, 6 x 6 4-TON, 6 x 6
TRAILER, FULL, FLAT BED	16	7,400 TO 15,330	32,000 TO 40,000	39,400 TO 55,330	28.8	8.5	5.0	33	11 [5]	967 [3]	12	1	AIR	6-TON, 6 x 6
TRAILER, FULL, FLAT BED	20	15,676	40,000	55,676	35.3	9.5	5.1	40	17 [5]	1,080 [3]	12	1	AIR	6-TON, 6 x 6
SEMITRAILER, FLAT BED, WITH DOLLY [4]	20	12,790 TO 16,700	40,000	52,790 TO 56,700	39.0	8.5	5.6	36 TO 40	10 [5]	1,885 [3]	12 OR 20	1	AIR	6-TON, 6 x 6
TRAILER, FULL, LOW BED	60	23,600	120,000	143,600	35.5	8.0	3.9	31	— [5]	NOT LISTED	24	1	AIR	6-TON, 6 x 6

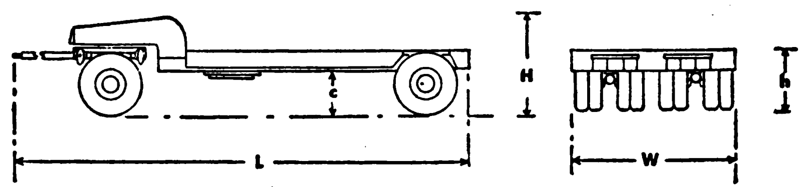
[1] BRAKES ARE AIR-OPERATED WHEN TRAILER IS BEING TOWED. PARKING BRAKES ARE HAND-OPERATED.

[2] SHIPPING DIMENSIONS, KNOCKED DOWN.

[3] SHIPPING DIMENSIONS, CRATED FOR EXPORT, FULLY ASSEMBLED

[4] DIMENSIONS AND WEIGHTS VARY WITH MANUFACTURER.

[5] REAR WHEELS SPAN THE TOTAL WIDTH. TRAILER WILL NOT CROSS THE STEEL-TREADWAY BRIDGE.



ficient where equipment must be hauled more than 2 miles. Trailers should be loaded as close as possible to their rated capacity.

c. Supervision for efficient use. The following suggestions will aid equipment supervisors in obtaining maximum efficiency in use of trailers:

(1) *Maintenance.* (*a*) Preventive maintenance work and necessary first echelon repair must be done daily. Follow proper maintenance manuals and charts.

(*b*) Check air and hand brakes before and after each trip.

(2) *Loading.* (*a*) Use low banks or built-up earth ramps where possible (fig. 93).

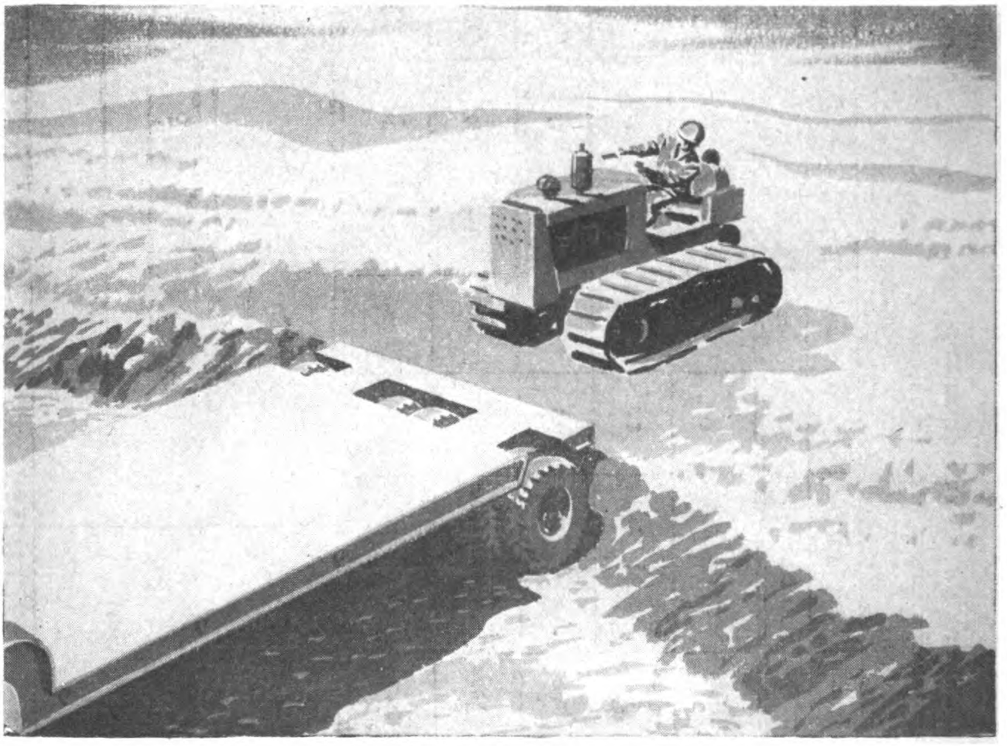


Figure 93. Using a low bank as a loading ramp.

(*b*) Loading ramps are, however, carried on trailers at all times. They are used in loading from level ground and to prevent damage to trailer tires and the rear of the trailer.

When using ramps to load crawler-mounted equipment, run the machine slowly up the ramp and stop at the balance point. Roll ahead carefully until the machine rocks forward onto the trailer.

(*c*) In all loading, have a man on the trailer direct the equipment operator to keep the machine centered on the ramp and trailer.

(3) *Securing equipment on trailers.* (*a*) Block and chock all equipment in position and chain and lash it to the trailer bed.

(*b*) Position shovels as far forward on trailers as possible (fig. 94). Lower boom and dipper stick as far as possible, resting dipper in truck body.

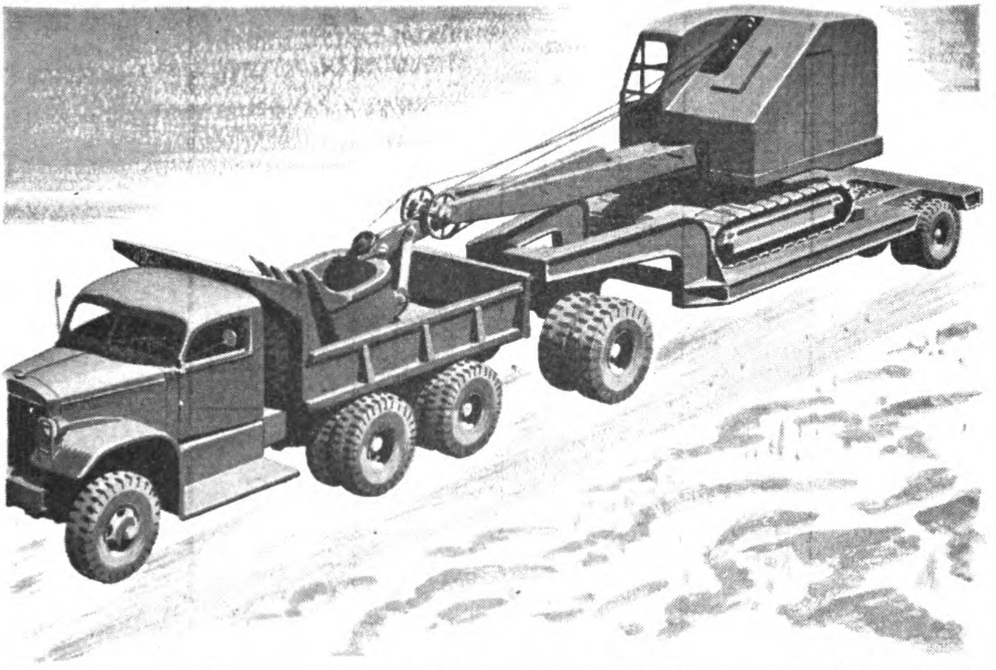


Figure 94. Shovel loaded on a trailer. Keep the truck cab door unlatched, and crib the bucket to protect the truck body.

(4) *Unloading.* Heavy equipment must be unloaded slowly to minimize damage to trailer. Procedure is the reverse of that in loading.

Section VII. GRADERS

42. PHYSICAL CHARACTERISTICS. See table XXIII for dimensions and weights of graders.

43. USE OF GRADERS. a. Purpose. Graders are multipurpose earth-moving and shaping machines used in construction and maintenance of roads and runways.

b. Controlling factors. Use of graders is controlled by the type of operation, distance material must be moved, and the type and condition of material to be handled.

(1) *Type operation.* Graders are most effective during later stages of a project, on operations such as leveling, shaping, mixing, spreading, and sloping. They are also useful in preliminary work such as ditching and light stripping. Graders are not suitable for heavy excavation.

(2) *Moving material.* Graders move large quantities of material short lateral distances in the process of side-casting. They are not designed to haul in the direction of travel.

(3) *Type of material.* Graders move, without supplemental equipment, light and medium soil free from root masses, stumps, and boulders. Unconsolidated materials such as loose sand or gravel are ideal for grader operation. Heavy or consolidated material requires the

Table XXIII. Physical characteristics of graders

Equipment	Over-all dimensions			Weight (pounds)	Remarks
	Length (inches)	Width (inches)	Height (inches)		
Grader, road, towed, leaning-wheel, 6½-foot moldboard, hand-controlled[1]	With tongue extended, 182 With tongue turned under, 145	w/o blade, 70 w/blade extended, 78	66	1,850	10 to 15 dbhp required Towing speed in transit 15 to 20 mph. Operating speed: see table of tractor speeds (table IV)
Grader, road, towed, leaning-wheel, 12-foot moldboard, hand-controlled	390	w/o blade, 118 w/blade extended, 144	98	10,000	50 dbhp required Towing speed in transit 10 to 15 mph. Operating speed: see table of tractor speeds (table IV)
Grader, road, motorized, 12-foot moldboard, Diesel-engine-driven	302	w/o blade, 91 w/blade extended, 144	w/o cab, 86 w/cab, 120	w/o scarifier 20,800 w/scarifier 22,150	See table XXIV for speed in various gears

[1] Performance is improved by adding weight on operator's platform. Three-hundred pounds of sand in bags is recommended.

auxiliary use of scarifiers or tractor-drawn rooters. Extremely wet or muddy soil causes the front wheels of the grader to bog down and operation becomes difficult or impossible. Dry sand, on the contrary, has a tendency to pile up and run over the moldboard.

44. ESTIMATING WORK OUTPUT. a. Work output formula. The time required to complete a grader operation depends on the number of passes necessary and the speed maintained on each pass. Speed is regulated by the type of material handled. The following work-output formula is used to estimate the total time in hours required to complete a grader operation:

$$\text{Total time} = \frac{P \times D \times E}{S} + \frac{P \times D \times E}{S_1} + \cdots\cdots$$

Where, P = the number of passes required.
D = the distance traveled on each pass.
E = grader efficiency factor.
S = speed of tractor or motorized grader.

b. Factors in formula. (1) *Number of passes* (P). The number of passes depends on the operation and can be estimated before construction begins.

(2) *Distance (D).* Distance traveled in each pass is in miles and can be determined before construction begins.

(3) *Efficiency factor (E).* Grader efficiency factor takes into account the fact that a 60-minute work hour is rarely attained. Efficiency varies depending on supervision, operator skill, maintenance requirements, and site conditions. The average value of 80 per cent used in the following example is normal but must be checked on each job by observation and experience.

(4) *Speed (S).* Speed is in miles per hour. As work progresses, conditions may require increasing or decreasing speed on subsequent passes. The work-output formula must be solved in as many parts as there are speeds used. The sum of the values obtained in each part is the total time required for the operation. Care must be taken to use the correct number of passes for each speed used. See table XXIV for speeds of motorized graders; use tractor speeds in table IV for towed graders.

Table XXIV. Speeds of motorized graders in various gears

		Forward								Reverse	
Gear		1st	2nd	3rd	4th	5th	6th	7th	8th	Low	High
MPH	Min	1.00	1.28	1.83	2.49	3.00	4.10	4.90	7.60	1.37	1.87
	Max	1.73	2.66	3.80	5.17	6.30	8.50	10.2	15.9	2.86	3.89

c. Example: Five miles of gravel road to be leveled and reshaped by motorized grader.

Five passes necessary to complete leveling and reshaping.

Type of material permits passes 1 and 2 at 1.28 mph, passes 3 and 4 at 2.49 mph, and pass 5 at 3.00 mph.

Efficiency factor = .80.

Substituting in work-output formula:

$$\text{Total time} = \frac{\overset{(P)}{2} \times \overset{(D)}{5} \times \overset{(E)}{0.8}}{\underset{(S)}{1.28}} + \frac{\overset{(P)}{2} \times \overset{(D)}{5} \times \overset{(E)}{.80}}{\underset{(S_1)}{2.49}} + \frac{\overset{(P)}{1} \times \overset{(D)}{5} \times \overset{(E)}{.80}}{\underset{(S_2)}{3.00}}$$

$$= 6.25 + 3.21 + 1.33$$

$$= 10.8 \text{ hr}$$

45. SUPERVISION FOR MAXIMUM WORK OUTPUT. Supervisors responsible for obtaining maximum grader efficiency should keep the following considerations in mind.

a. Selection of tractor-grader combinations. (1) Graders should have a weight of from 700 pounds per linear foot of blade length on light work to 900 pounds per linear foot on heavy work.

(2) Tractors used should have the greatest number of speeds between 1½ and 3½ mph and should weigh from 1.9 to 2.2 times as much as the grader.

b. Eliminating unnecessary turns. When a motorized grader makes a number of passes over a distance less than approximately 1,000 feet, it is normally more efficient to back the grader the entire distance to the starting point than to turn the grader around and continue work from the far end. (See figure 95.) Never make turns on newly laid bituminous road or runway surfacing.

c. Proper tire inflation. Proper inflation of the tires of motorized graders is necessary to obtain maximum effectiveness from engine horsepower. Over-inflated tires mean a small contact area between tires and road surface and a loss of traction. To increase traction, tire pressure may be as low as 15 pounds per square inch (psi) without harmful effect to the tires. For best results, pressure should normally be between 20 to 25 psi. Pressures among tires must be within 1 psi of each other. Difference of pressure in rear tires will cause wheels to slip and the grader to *buck*.

d. Maintaining haul roads. When towed or motorized scrapers, dozers, or dump trucks are performing a large earth-moving operation, efficiency is increased if haul roads are kept in condition, permitting high-gear operation. Graders are the best machines for maintaining haul roads. The towed grader is more efficient than the motorized grader for maintaining side ditches during wet weather.

e. Working in tandem. When maintaining roads, it is most efficient to use enough graders to complete one side of a road with one pass of each grader. In this way, one side of the road is completed while the other side is left open to traffic. Operations such as leveling, mixing, and spreading are expedited by using graders in tandem (fig. 96).

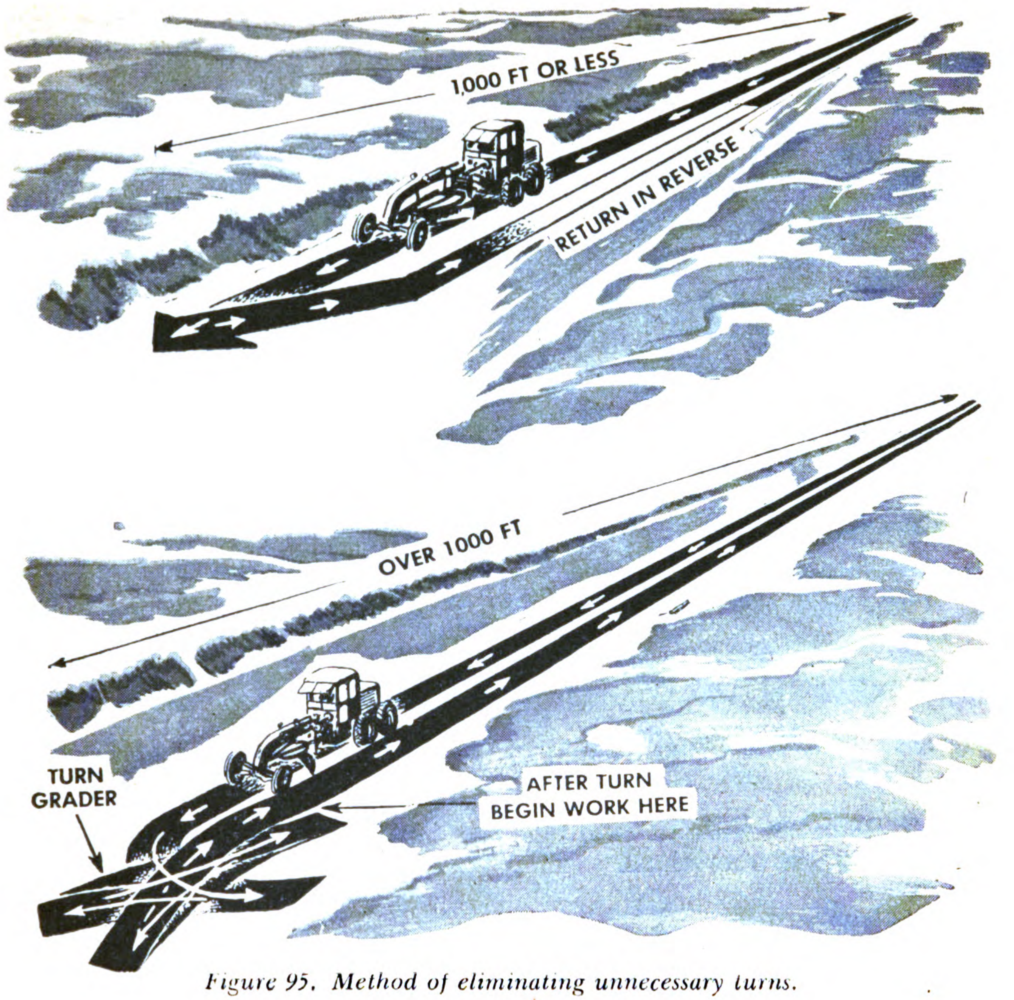


Figure 95. Method of eliminating unnecessary turns.

f. Planning. Efficiency of grader operations is in direct proportion to the number of passes made. Proper planning is of utmost importance in eliminating unnecessary passes.

For example, 5 miles of road is to be maintained. Condition of road allows a speed of 1.83 mph. Five passes are necessary to complete the job, but because of improper planning seven passes must be made.

Time with 5 passes:	*Time with 7 passes:*	*Increase*
(P) (D) $\frac{5 \times 5}{1.83} = 13.66$ hr (S)	$\frac{7 \times 5}{1.83} = 19.13$ hr	40% or 5.47 hr

g. Effect of rain on grading operations. Construction operations are hindered by rain but maintenance operations can be performed best after a rain. Graders should be used for maintenance operations during the short period following a rain when soil is damp (no longer muddy but not yet dry).

h. Proper working speeds. Operations should be performed as fast as possible consistent with the skill of the operator and ability of the

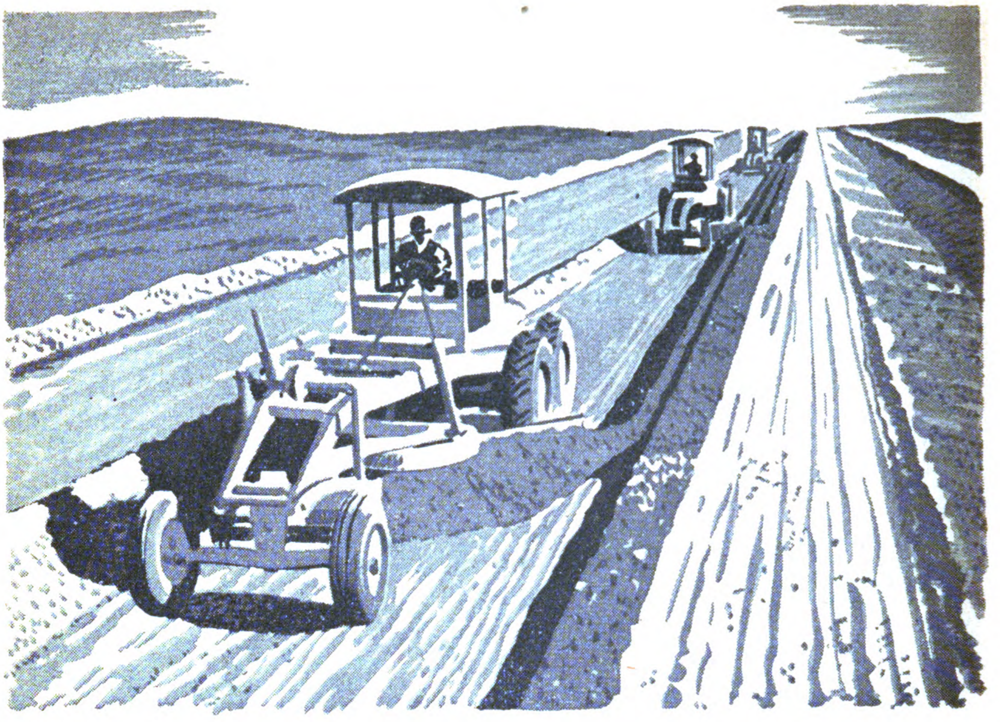


Figure 96. Method of mixing windrow with graders in tandem taking successive bites.

grader to move without stalling. See table XXV for gears normally used in various operations.

Table XXV. Gears normally used for various operations

Operation	Gear range[1]
Maintenance	3rd–5th.
Spreading	2d–4th.
Mixing	4th–6th.
Ditching	1st–2d.
Bank sloping	1st.
Snow removal	7th–8th.
Stripping	1st–2d.
Finishing	2d–4th.

[1] See table XXIV for speeds in various gears.

i. Grading in reverse. Skilled operators can increase the efficiency of an operation by working in reverse when distances are short and turning is impractical. See paragraph 45b and figure 95.

j. Maintenance. Road maintenance should begin at the first signs of rutting of *washboarding*. If these conditions are not corrected immediately, more passes will be required when the operation is finally performed.

46. PROPER OPERATING TECHNIQUE. Following are the proper techniques to be used in the various operations performed by graders:

a. Road construction without supplementary equipment. Cutting ditches and building the crown of an earth road can be done in the following seven basic steps:

(1) *Cutting ditches.* (*a*) *Marking cuts.* Better grader control can be maintained and straighter ditches cut if a 3- to 4-inch-deep *marking cut* is made at the outer edge of the bank slope on the first pass. (See figure 97.)

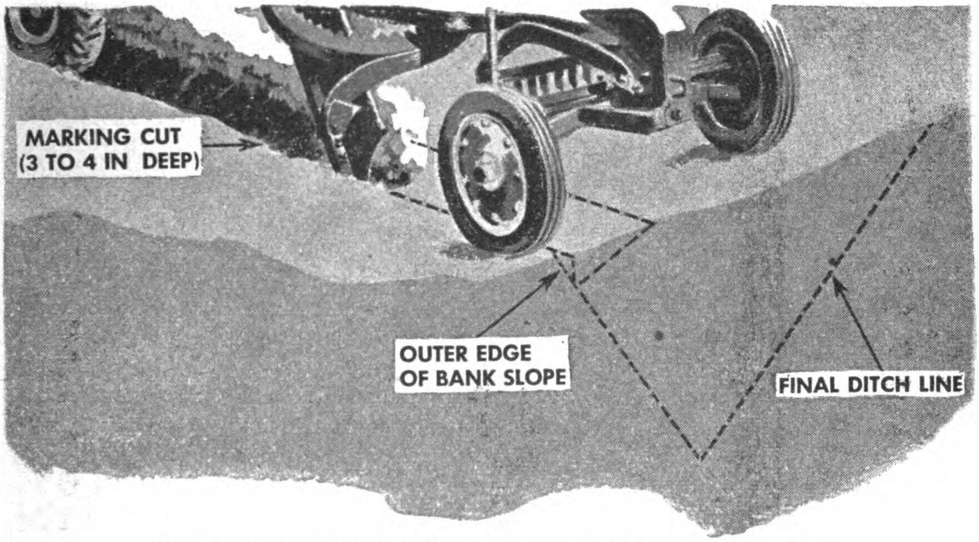


Figure 97. Cutting marking cut for control and accuracy.

(*b*) *Ditch cuts.* When cutting ditches, each cut should be made as deep as possible without losing control of or stalling the motorized grader or tractor. Each successive cut should be brought in from the edge of the bank slope so the toe of the blade will follow the bottom of the ditch on the final cut. (See figure 98.)

(2) *Moving windrows.* As ditch cuts are made, windrows are formed between the heel of the blade and the left rear wheel. When the ditch is at the required depth or the windrow reaches a height greater than that of the bottom of the grader, the windrow must be moved and leveled off. See figure 99. Shoulder is formed during this operation.

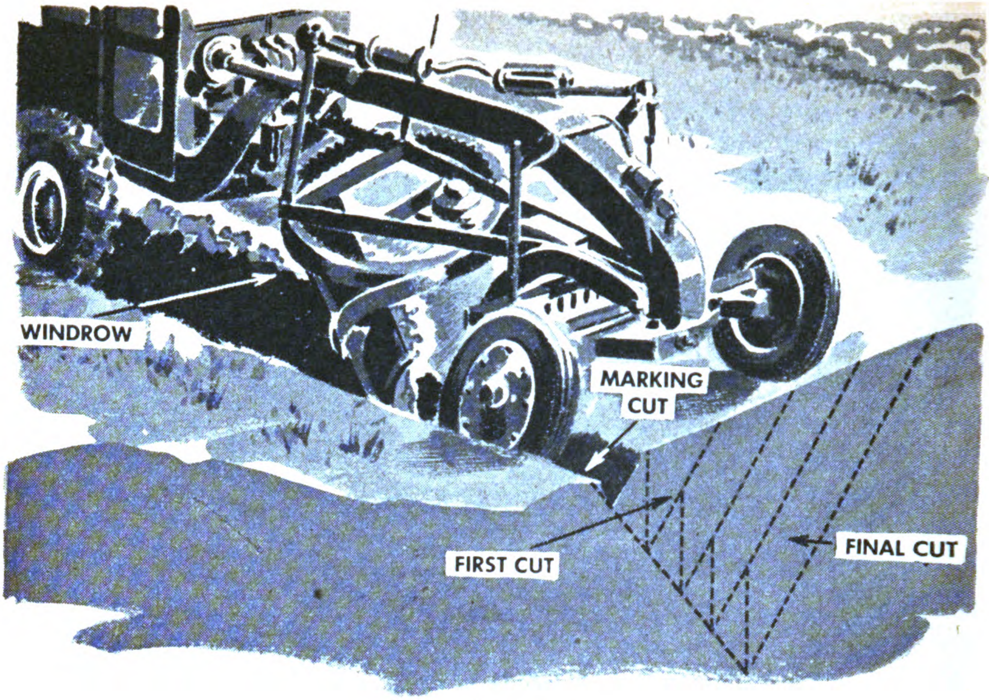
(3) *Leveling windrows.* This operation forms the crown of the road. All material should spill off under the blade as the material is leveled. There should be no windrow at the heel of the blade. See figure 100.

(4) *Sloping the bank.* This operation is necessary to prevent erosion of the bank slope from filling the ditch. With the bank slope cut in steps as shown in figure 98, it is only necessary to smooth the ridges. Material from the ridges falls off into the ditch. (See figure 101.)

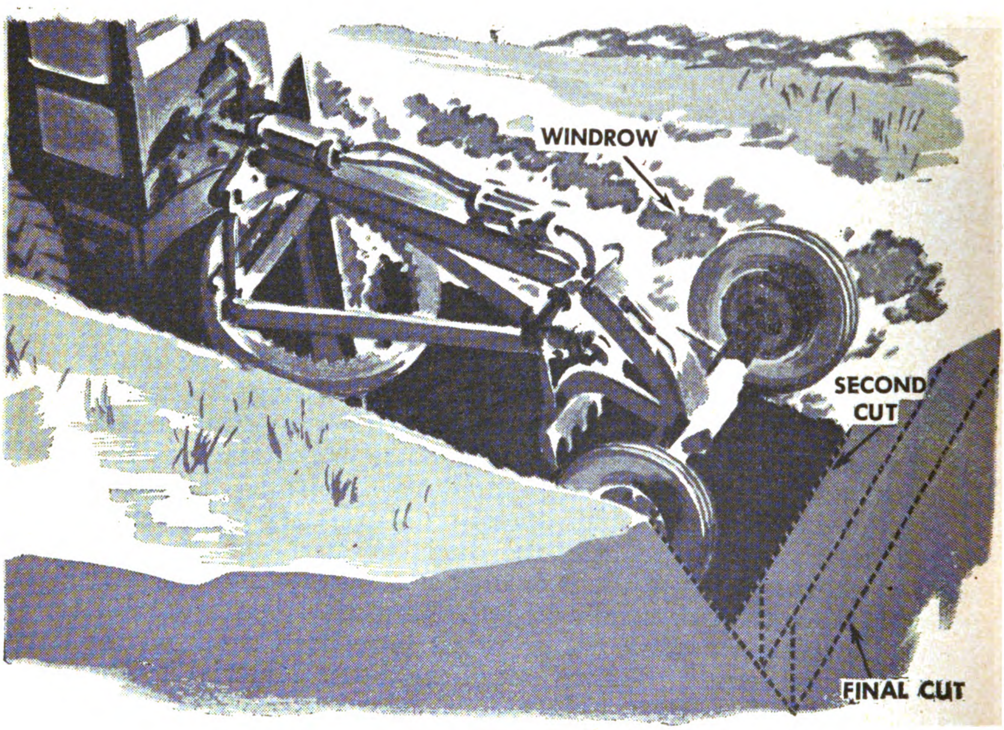
(5) *Cleaning the ditch.* After ridges have been cut from the bank slope, material must be cleaned out of the ditch. Material is thrown on the shoulder. (See figure 102.)

(6) *Moving windrow and finishing shoulder.* The windrow formed by cleaning the ditch is moved onto the road and at the same time the shoulder is finished to the desired slope and smoothness. (See figure 103.)

(7) *Spreading windrow on crown.* The windrow formed during the



① *Marking cut.*



② *Intermediate cut.*

Figure 98. Steps in cutting ditch.

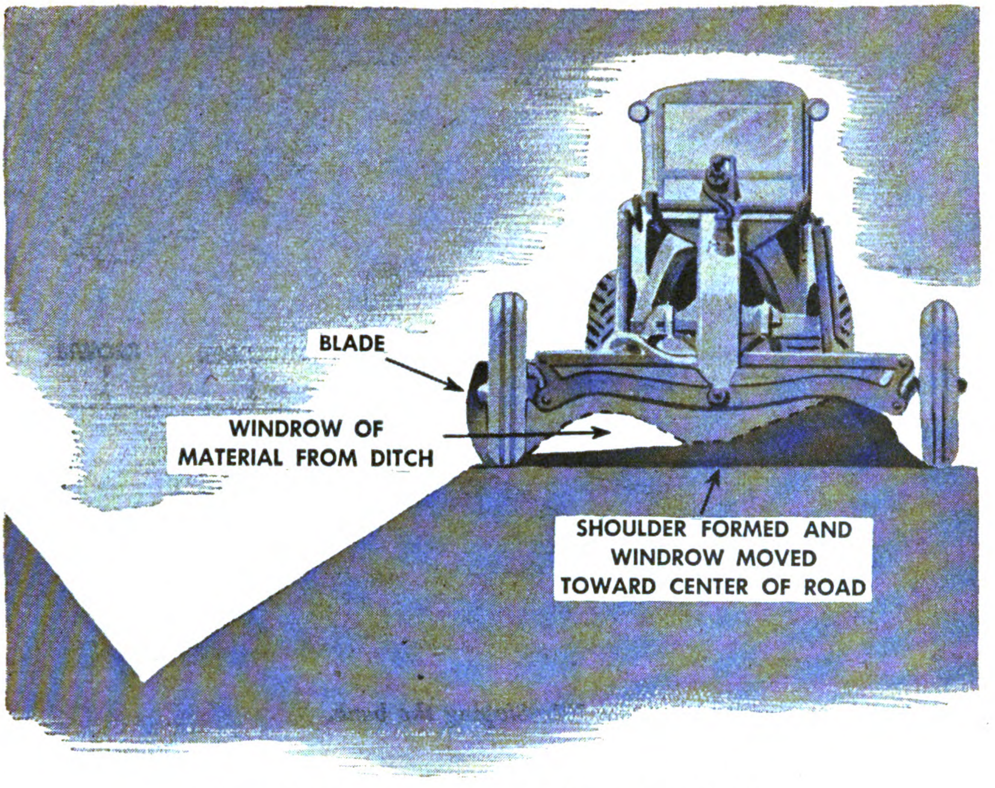


Figure 99. Moving windrow and forming ***shoulder.***

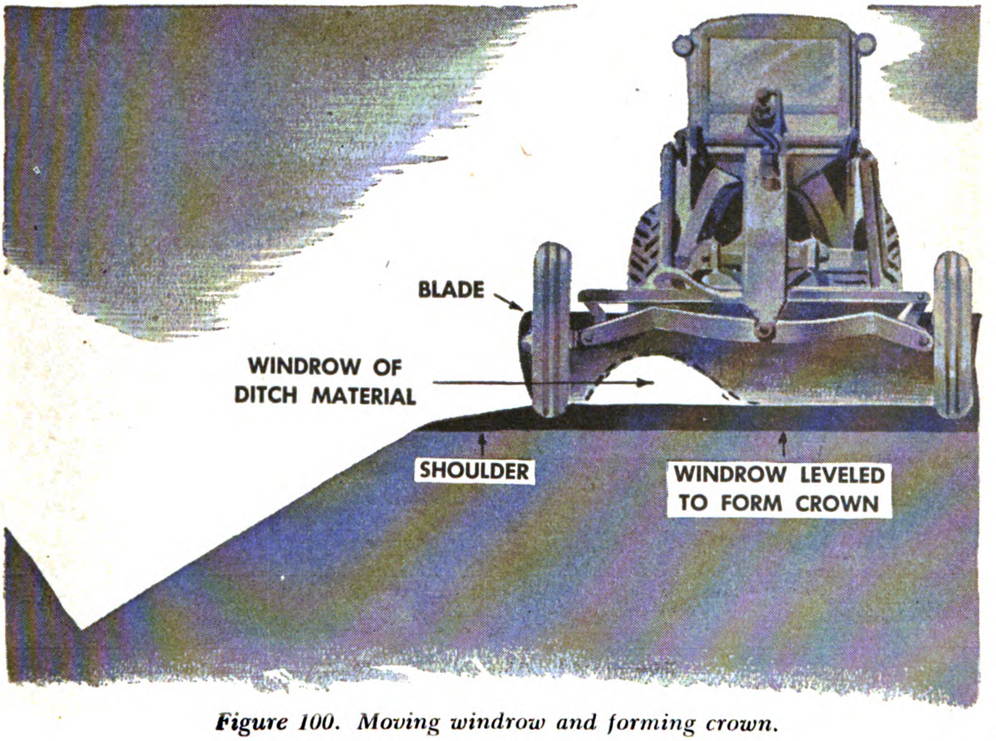


Figure 100. Moving windrow and forming crown.

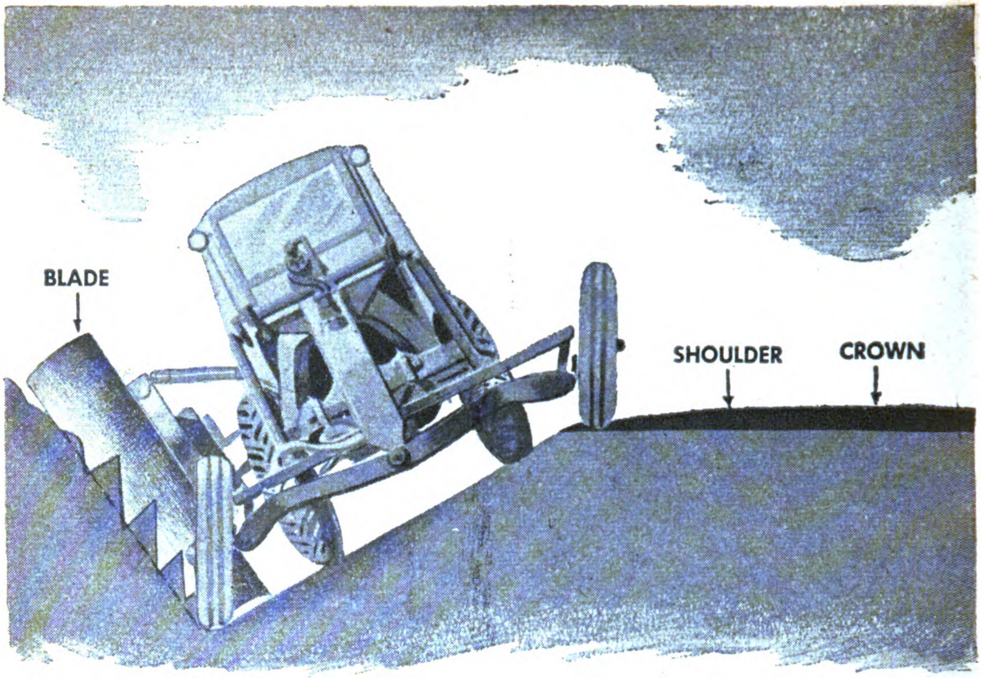


Figure 101. Sloping the bank.

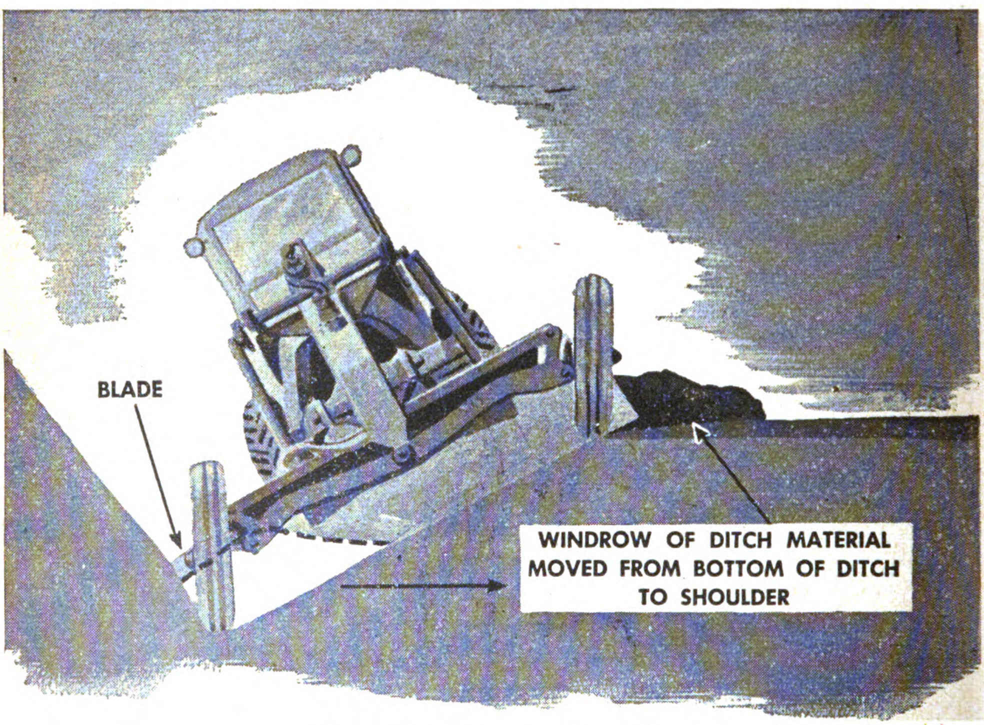


Figure 102. Cleaning the ditch.

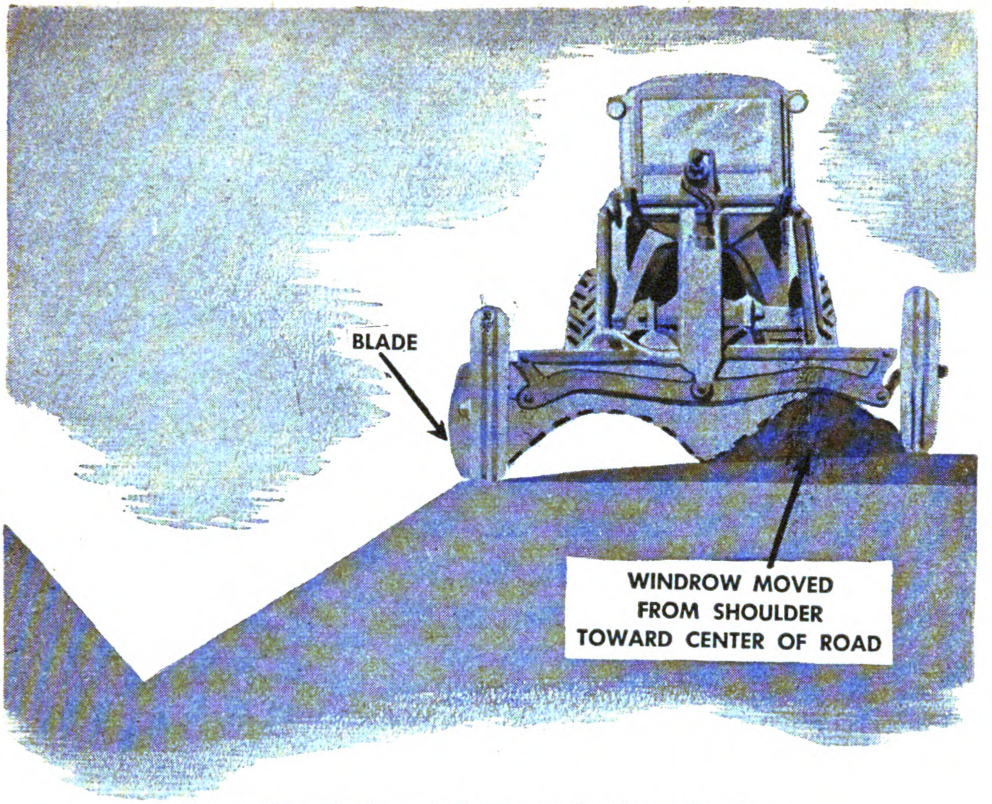


Figure 103. Moving windrow and finishing shoulder.

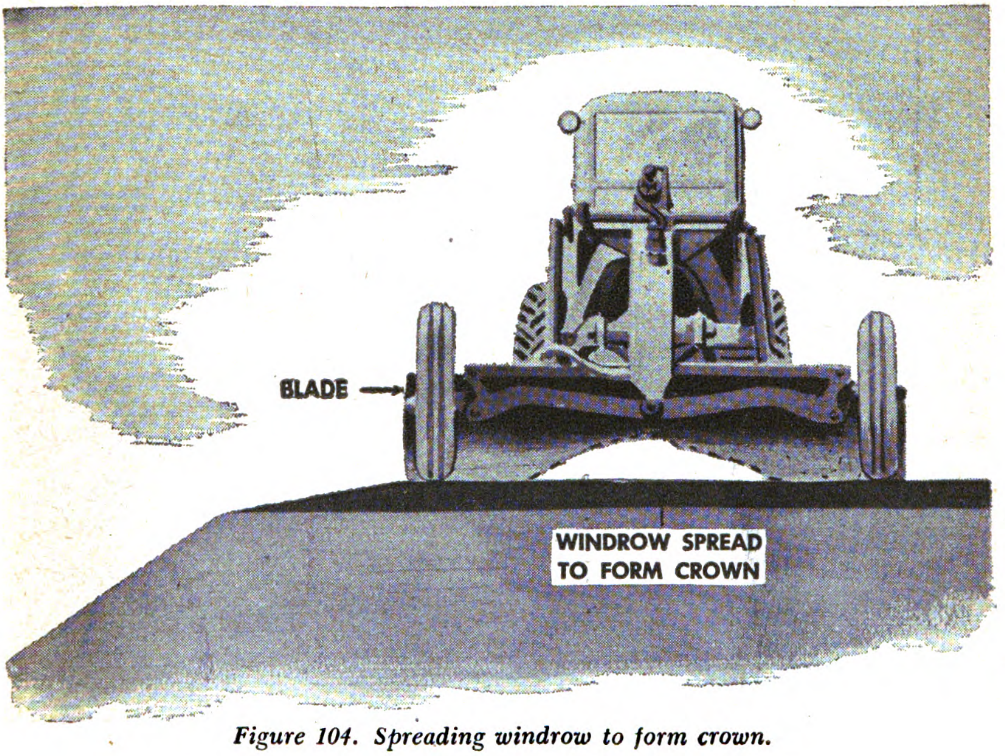


Figure 104. Spreading windrow to form crown.

shoulder-finishing operation is spread on the road to form the desired crown. (See figure 104.)

Note. This method of road building can be adapted to any size road by increasing or decreasing the number of steps. The number of steps used depends on the urgency of completion. If construction must be expedited, bank slopes can be eliminated and the road constructed in the first three steps. When using motorized graders on short roads less than 1,000 feet long, it is normally more efficient to finish one side at a time by backing the length of the road after each operation instead of turning the grader.

b. Construction of various size roads. (1) *Constructing a 10-foot-wide road in two round trips.* Figure 105 ① shows dimensions of the completed road. The following steps are taken to complete the road. See figure 105 ②:

Step 1. Cut ditch approximately 9 inches deep and 4 feet wide. Deposit material in a windrow in roadway.

Step 2. Spread material in windrow to form a smooth surface sloping toward side ditches.

Note. Each step requires two passes, one on each side of road.

(2) *Constructing a 12-foot-wide road in three round trips.* Figure 106 ① shows dimensions of the completed road. The following steps are taken to construct the road. See figure 106 ②:

Step 1. Cut ditch approximately 9 inches deep and on a slope of *1 on 4*. Deposit material in a windrow in roadway.

Step 2. Repeat step 1, cutting ditch 12 inches deep. Move material plus a portion of the windrow left on first trip further toward center of roadway.

Step 3. Spread material in roadway to form a smooth surface sloping toward side ditches.

Note. Each step requires two passes, one on each side of road.

(3) *Constructing an 18-foot-wide road in five round trips.* Figure 107 ① shows dimensions of the completed road. The following steps are taken to complete the road (fig. 107 ②):

Step 1. Cut ditch 15 inches deep and approximately 3½ feet wide. Deposit material in a windrow on road.

Step 2. Move material in windrow toward center of road.

Step 3. Repeat step 1, cutting ditch 30 inches deep and 4½ feet wide. Deposit material in a windrow in road.

Steps 4 and 5. Spread material in windrow to form a smooth surface sloping toward side ditches.

Note. Each step requires two passes, one on each side of road.

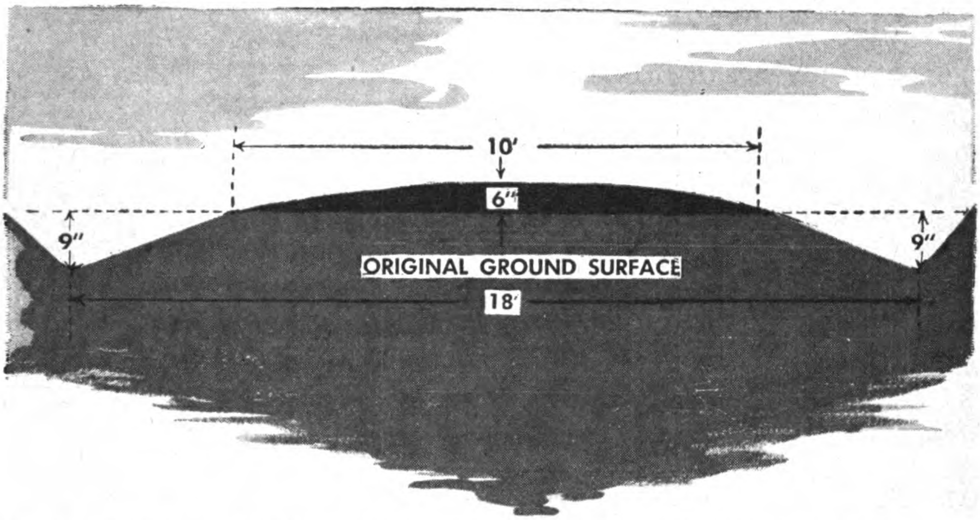
(4) *Constructing an 18-foot-wide road in seven round trips.* Figure 108 ① shows dimensions of the completed road. The following steps are taken to complete the road (fig. 108 ②):

Step 1. Cut ditch 15 inches deep and approximately 4½ feet wide.

Step 2. Move windrow formed by ditch cut toward center of roadway.

Step 3. Move material to approximate center of road.

Step 4. Repeat step 1, cutting ditch 24 inches deep with an inside slope of *1 on 2½*. Deposit material in a windrow on center of road.

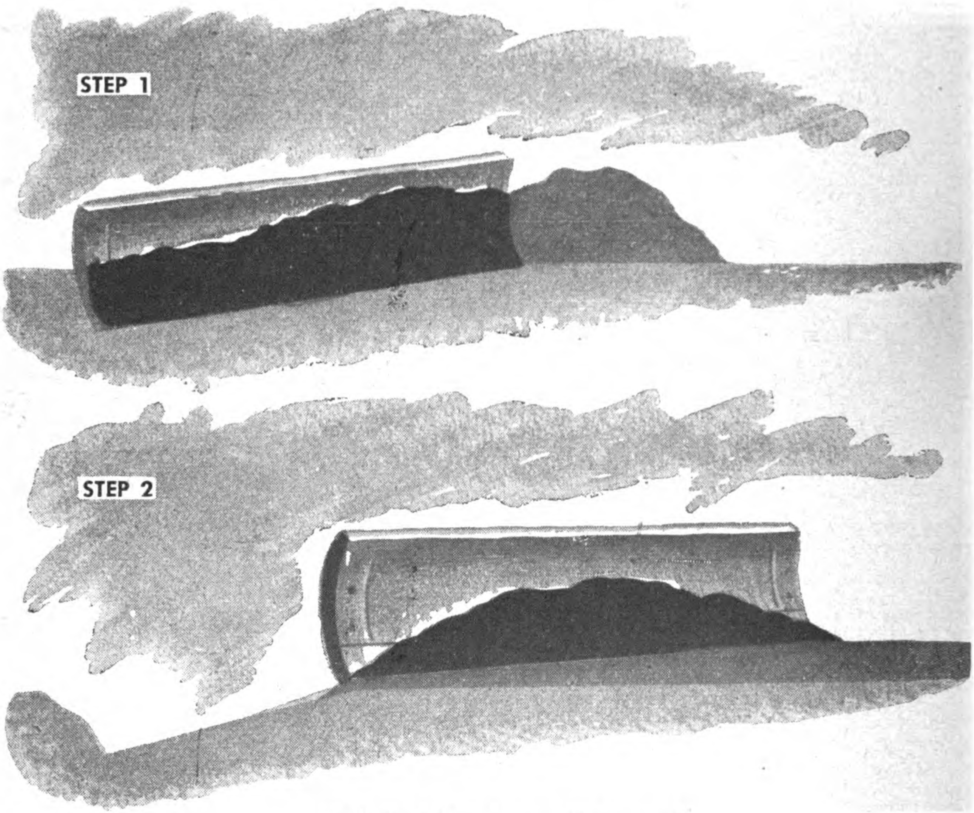


NOTE: 600 CU FT OF EARTH IS MOVED PER MILE OF FINISHED ROAD

LATERAL DISPLACEMENT IS 6 FT
APPROX 4/10 MILE CAN BE COMPLETED PER HOUR

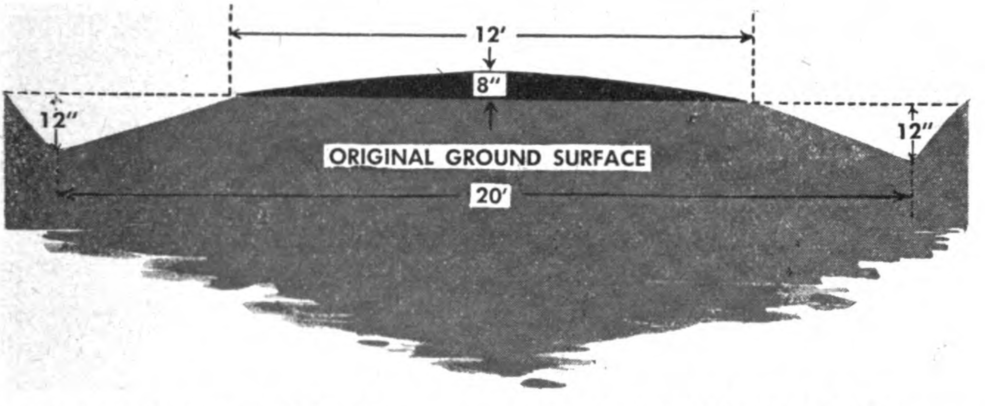
① *Dimensions.*

Figure 105. Ten-foot-wide road.



② *Steps taken to complete road.*

Figure 105. Ten-foot-wide road—**Continued.**

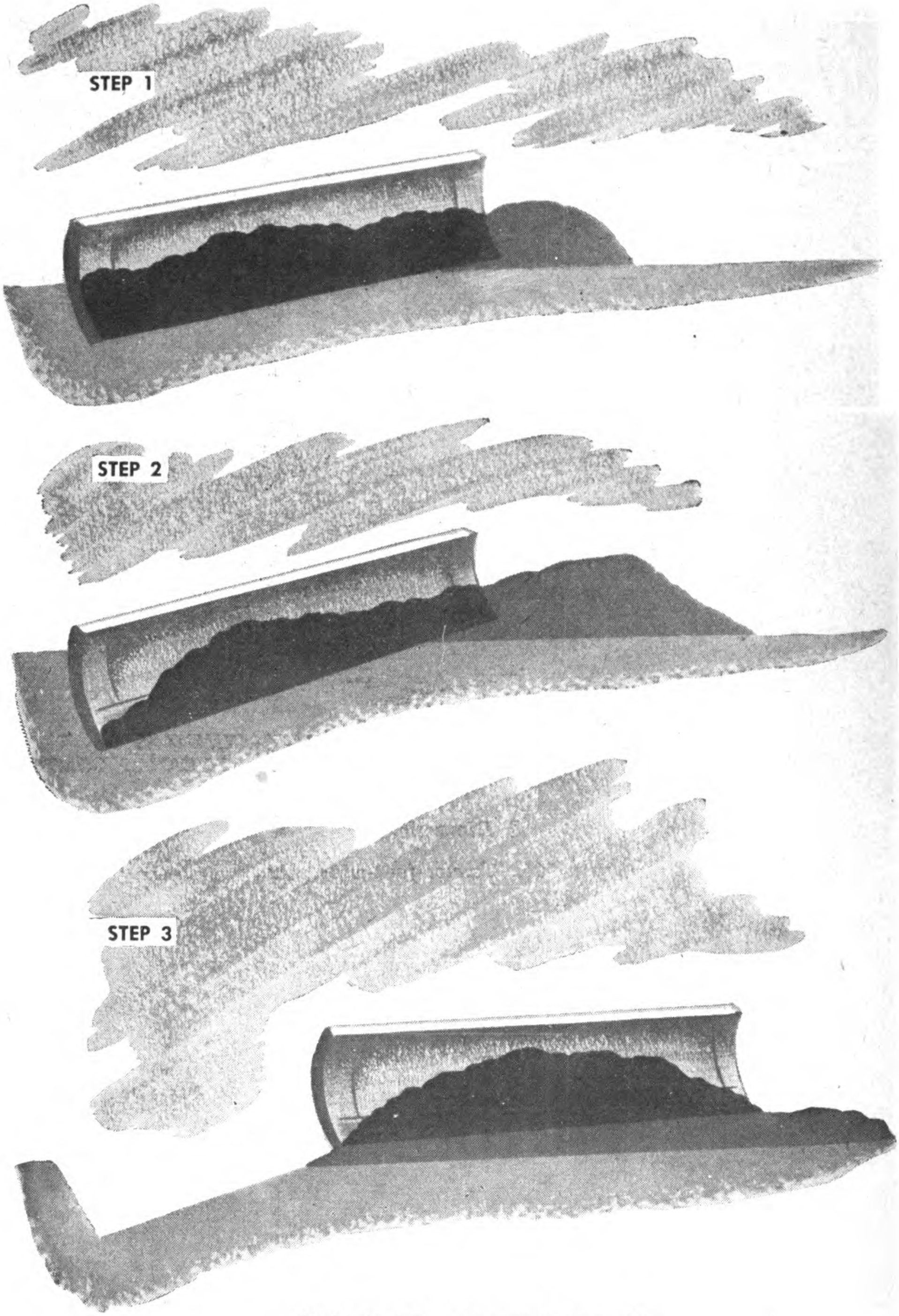


NOTE: 830 CU YD OF EARTH IS MOVED PER MILE OF FINISHED ROAD

LATERAL DISPLACEMENT IS 6½ FT
APPROX 3/10 MILE CAN BE COMPLETED PER HOUR

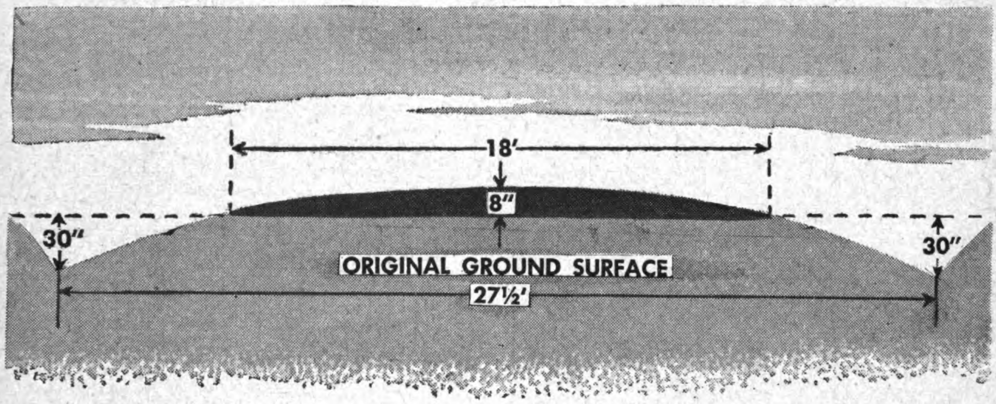
① *Dimensions.*

Figure 106. *Twelve-foot-wide road.*



② *Steps taken to complete road.*

Figure 106. Twelve-foot-wide road—Continued.

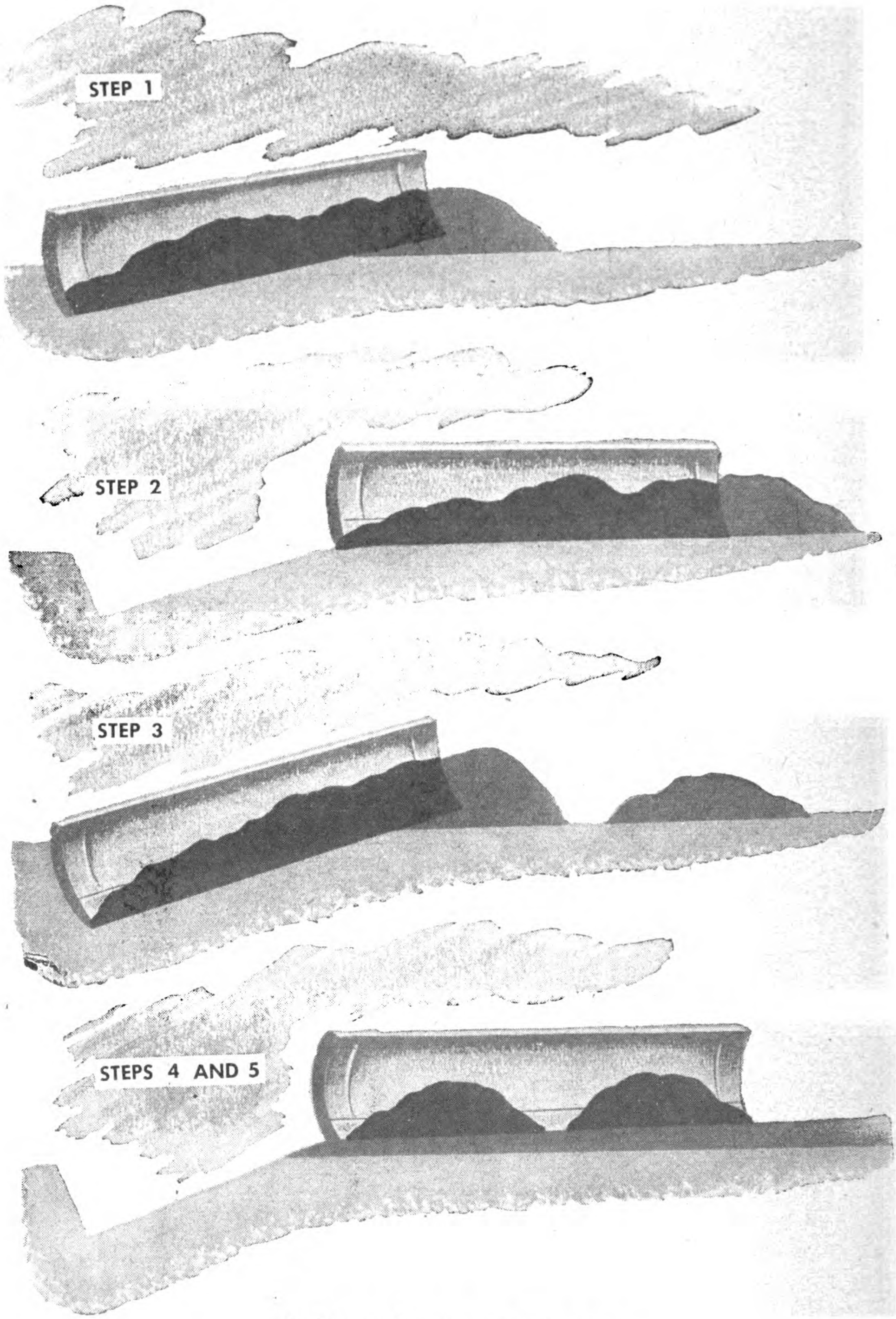


NOTE: 2,200 CU YD OF EARTH IS MOVED PER MILE OF FINISHED ROAD

LATERAL DISPLACEMENT IS 8¼ FT APPROX 2/10 MILE CAN BE COMPLETED PER HOUR

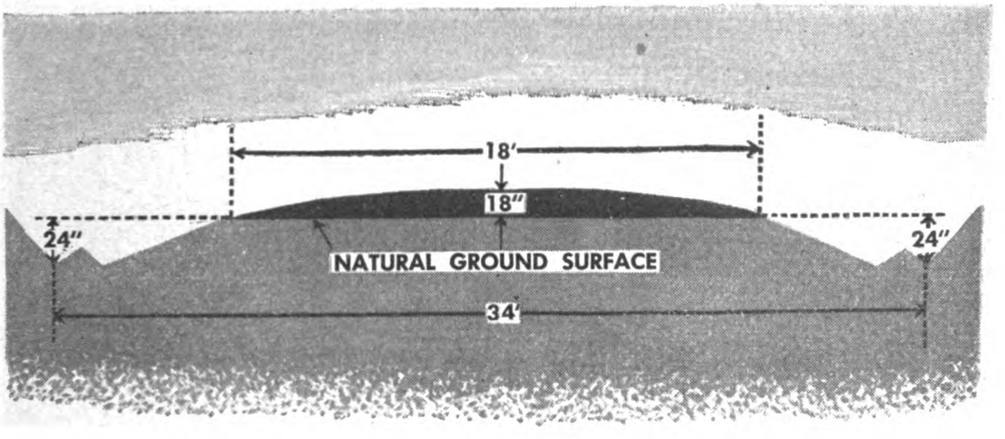
① *Dimensions.*

Figure 107. Five-step, 18-foot-wide road.



② *Steps taken to complete road.*

Figure 107. Five-step, 18-foot-wide road—Continued.

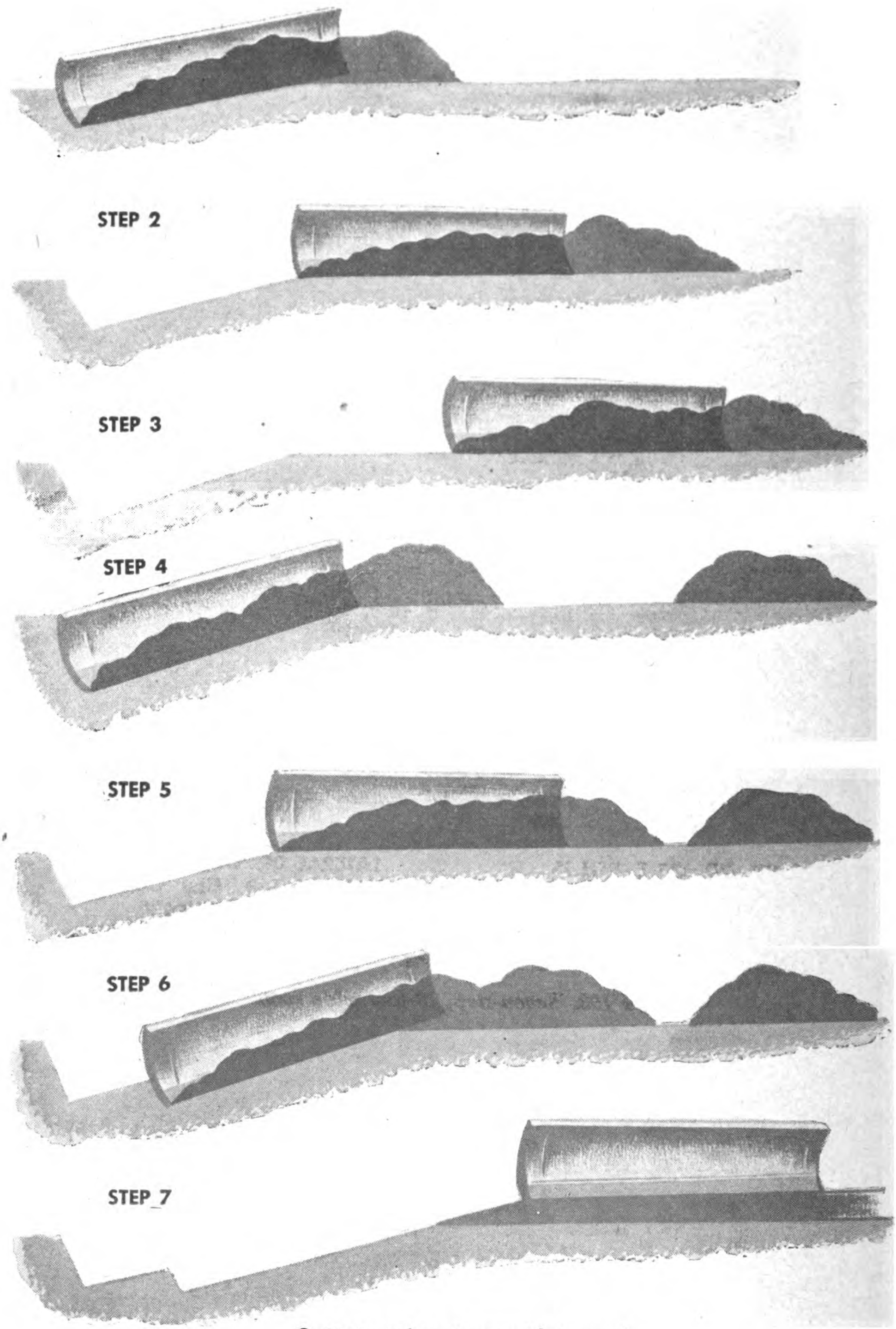


NOTE: 4,900 CU YD OF EARTH IS MOVED PER MILE OF FINISHED ROAD

LATERAL DISPLACEMENT IS 12 FT. APPROX 1/9 MILE CAN BE COMPLETED PER HOUR

① *Dimensions.*

Figure 108. Seven-step, 18-foot-wide road.



② *Steps taken to complete road.*

Figure 108. Seven-step, 18-foot-wide road—Continued.

Step 5. Move material in windrow toward center of road.

Step 6. Step-cut ditch with an inside slope of 1 on 2. Deposit material in a windrow on road.

Step 7. Spread material on road to form a smooth surface sloping toward side ditches.

Note. Each step requires two passes, one on each side of road.

c. Construction of access roads. Graders are efficient in constructing access roads for earth-moving equipment to and from construction sites.

d. Miscellaneous operations. See figures 109, 110, 111, 112, and 113 for proper methods of stripping, backfilling, spreading, mixing and finishing.

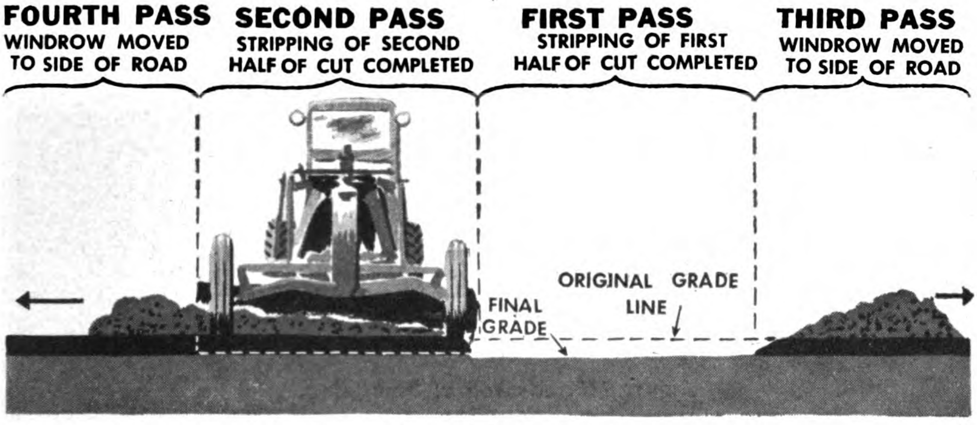


Figure 109. Method of stripping.

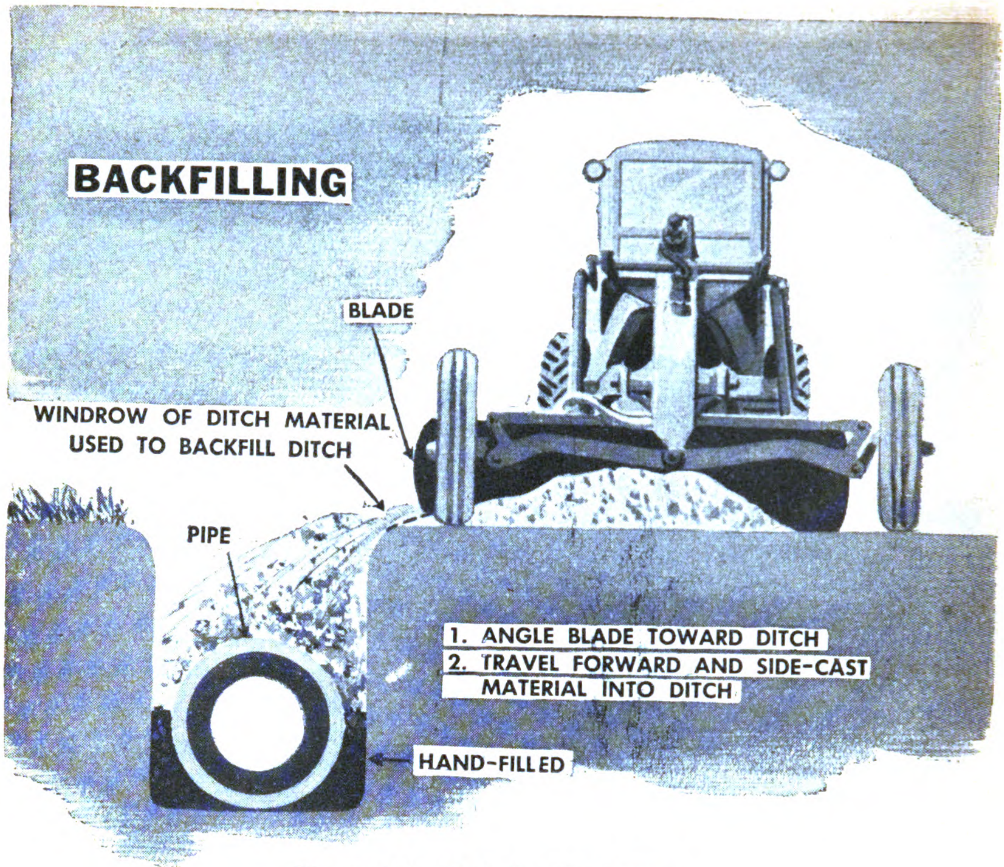


Figure 110. Method of backfilling.

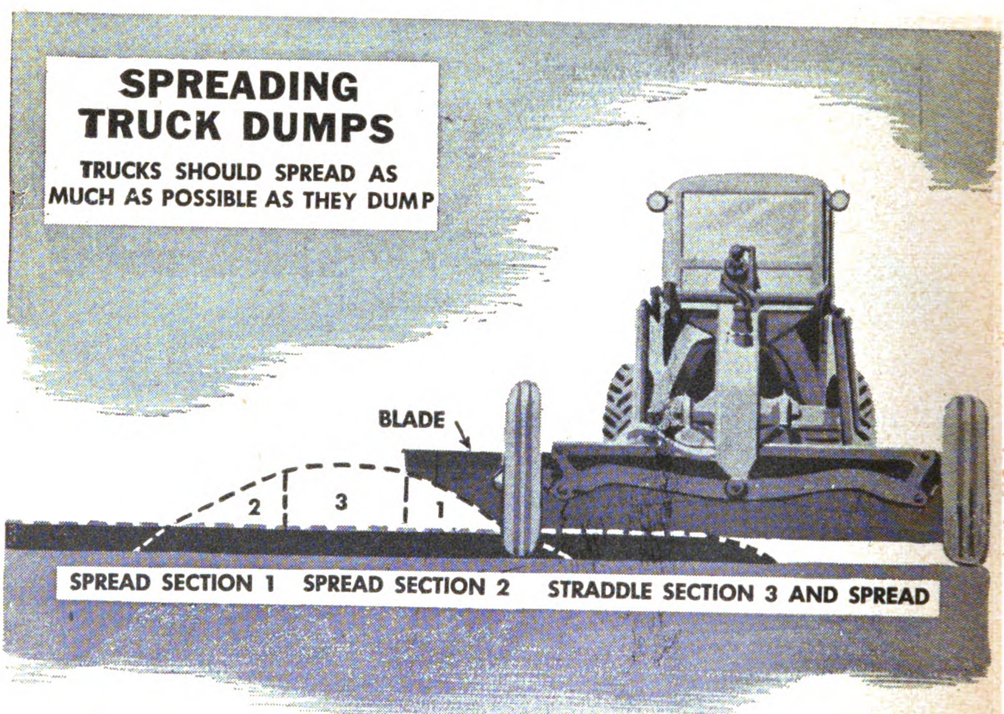


Figure 111. Method of spreading large truck dump.

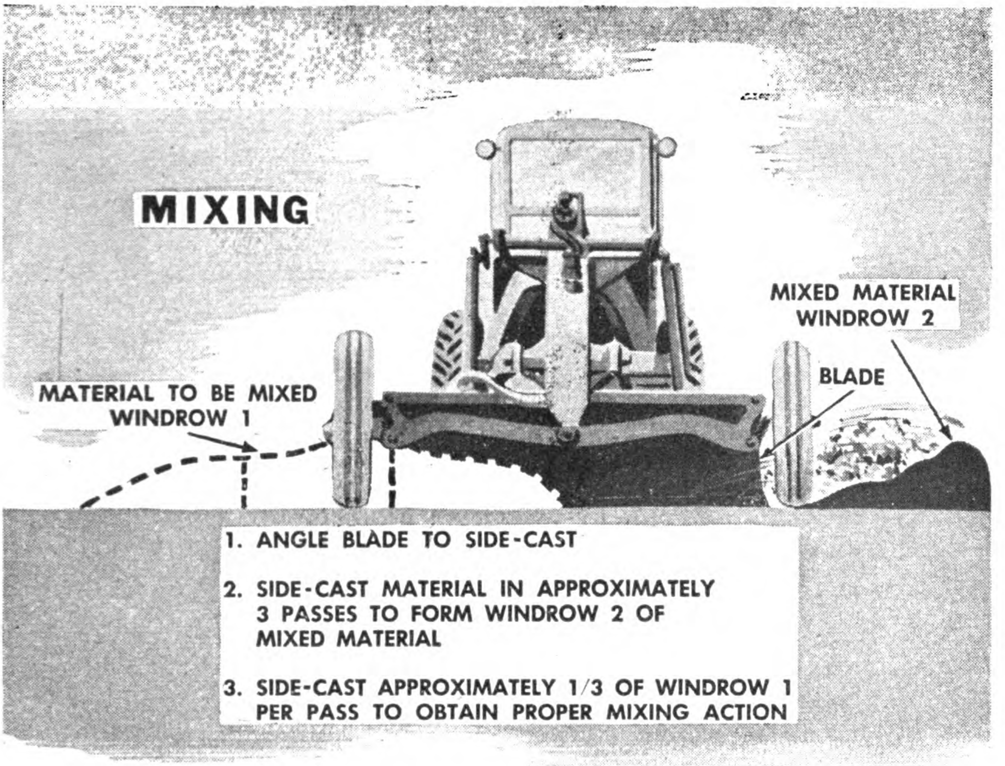


Figure 112. Method of mixing aggregates or aggregate and bituminous material.

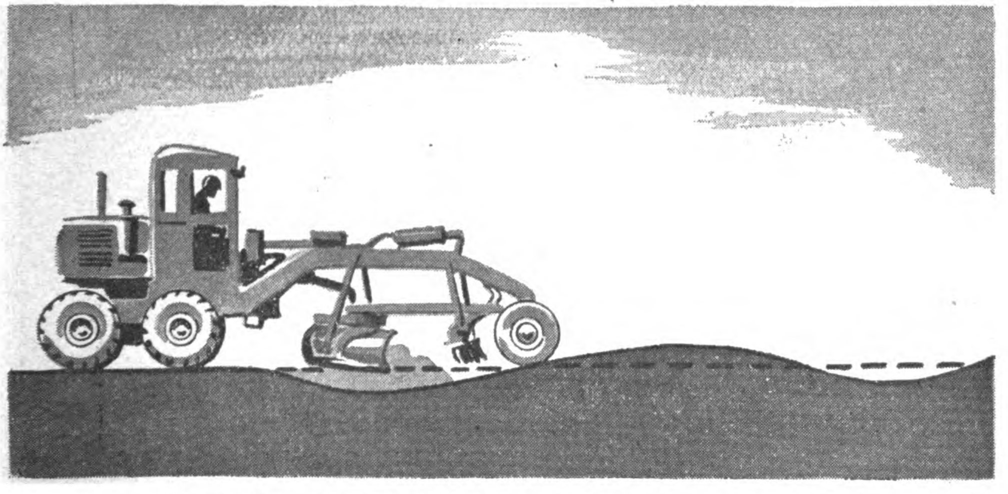


Figure 113. Method of finishing road or runway subgrades.

47. SUPERVISORS CHECK LIST. The following check lists are useful in determining efficiency of grader performance on various operations:

Operation	*Check list*
1. Leveling	1. Is blade set at a sharp enough angle to obtain proper slicing action?
	2. Is blade set at proper pitch to obtain cutting action?
	3. Is blade set so windrow falls either inside or outside of rear grader wheel? Windrow falling under wheel causes blade to raise and lower during travel, producing a wavy surfacing. Wheels of a motorized grader cannot get proper traction when traveling on a windrow.
2. Ditching	1. Is marking cut made approximately 4 to 6 inches deep?
	2. Is toe of blade directly behind front wheel?
	3. Is blade set so windrow falls inside rear wheels?
	4. Is windrow removed *before it reaches underside of grader?*
	5. Is the bank slope *step-cut?*
	6. Is the heel of the blade lowered to maintain inside slope of ditch?
3. Reshaping	1. Is maintenance performed in least possible number of passes?
	2. Is surface cut to bottom of all holes and *washboards?*
	3. Is material kept on road and not spilled into ditch?
	4. Is speed too fast, causing washboarding of surface?
	5. Is speed fast enough to maintain efficient operation?
	6. Has operation been planned so flow of traffic is not stopped?
4. Bank sloping	1. Is toe of blade at bottom of ditch?
	2. Is blade set to give maximum slicing action?
	3. Is grader working at highest possible speed consistent with its power and the operator's skill?

Operation	*Check list*
5. Scarifying	1. Are teeth penetrating too deep so subgrade is torn up and mixed with road surface? 2. If material is hard and consolidated, are enough teeth removed to give proper penetration? 3. Is machine traveling as fast as power will allow?
6. Mixing	1. Is blade pitched forward to obtain dragging action? 2. Are graders worked in tandem wherever possible? 3. Is blade taking too much material, preventing free rolling? 4. Is speed regulated to give proper mixing action and at the same time to allow full control of grader? 5. Is blade set to produce a free flow of material?
7. Spreading	1. Are there any signs of material not thoroughly mixed? 2. Is material being laid to proper thickness? 3. Are wheels being turned on freshly laid mix, causing a wavy surface?
8. Snow removal	1. Is grader speed high enough to throw material to one side? 2. Has preliminary reconnaissance been made to locate any large heavy objects that may be hidden under snow?

Section VIII. ROOTERS, PLOWS, CULTIVATORS, HARROWS, AND ROTARY TILLERS

48. PHYSICAL CHARACTERISTICS. See table XXVI for data on dimensions and weights of rooters, plows, cultivators, harrows, and rotary tillers.

Table XXVI. Physical characteristics of equipment

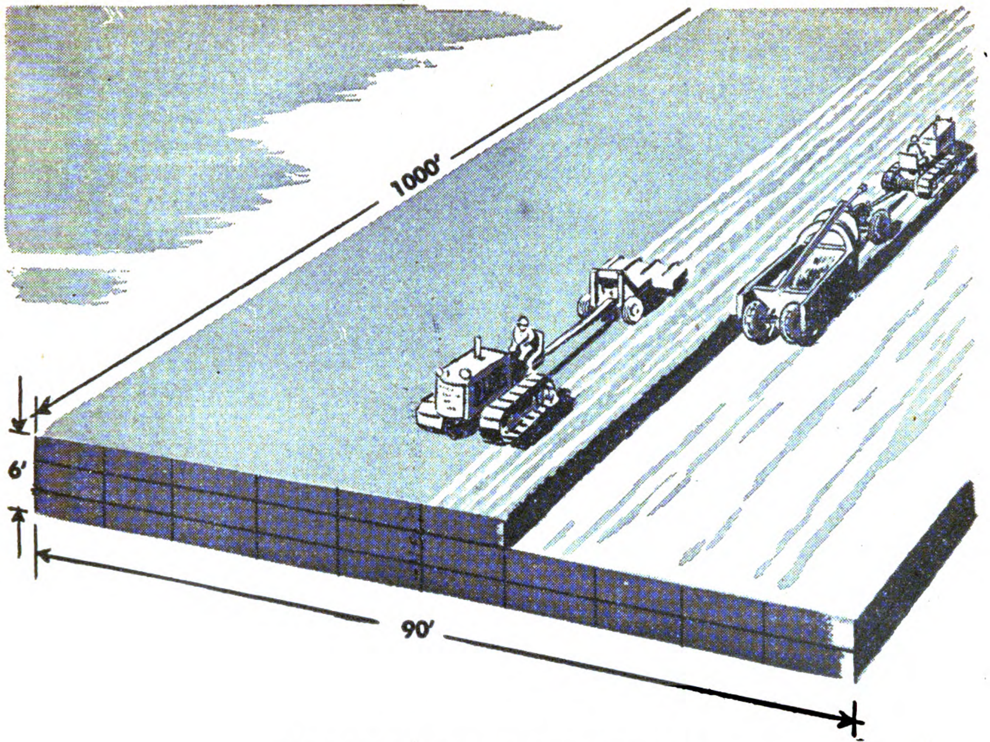
Equipment	Over-all dimensions				Remarks
	Length (in.)	Width (in.)	Height (in.)	Weight (lb.)	
Rooter, road, 3-tooth, cable-operated.	204	100	67	7,500	Max. depth of penetration—29 in. Distance between shanks c to c—43½ in.
Plow, bottoms and discs, towed, four 14-in. bottoms.				2,235	Working depth—6 to 14 in. Width of cut—56 in.
Plow, disc, towed, 28-in. disc.				5,550	Cutting depth—5 to 16 in. Cutting width—40 to 60 in.
Plow, tractor, w/standing cutter and single plain share.				1,700	Cutting depth— Min.—4 in. Max.—10 in. Cutting width— Min.—16 in. Max.—22 in.
Cultivator, chisel-tooth 12-in. spacing, 8 ft. wide.	147	96	48	2,370	Cutting depth—12 in. Cutting width—90 in.
Harrow, disc, offset, 24-in. discs, 8 ft. wide.	180	118	24	2,370	Working width—8 ft.
Harrow, spike-tooth, four-section.	120	240	--	540	Working width—20 ft.
Mixer, rotary-tiller, soil-stabilization, gas-engine-driven, trailer-mounted.	194	80	92	4,625	Working width—75 in. Mixing depth—8 to 10 in. Operating speed—1½ to 2½ mph.

49. USE OF EQUIPMENT. a. Rooters. (1) *Use.* Rooters are designed primarily to remove roots and to break up and loosen hard material before it is handled by scrapers and dozers. Solid rock must be broken up by explosives before using rooters to loosen it further.

(2) *Estimating work output.* Work output can be estimated from tractor speed and the number of passes required to loosen material properly. Tractor speed is based on type and condition of material and number of rooter shanks used. Estimates vary greatly in accuracy depending on the estimator, the tractor operator, and the uniformity of material. See figure 114 for example problem.

(3) *Supervision for maximum work output.* Supervisors responsible for obtaining maximum rooter efficiency should keep the following considerations in mind.

(*a*) Rooters should always be operated with maximum penetration of the shanks, using one, two, or three shanks according to the hardness of the material (fig. 115). The required number of shanks is determined by test, using the maximum number which the tractor can pull steadily in the given material.



EXAMPLE PROBLEM

GIVEN: THREE-TOOTH ROOTER WITH D8 TRACTOR
DEPTH SHANKS WILL PENETRATE - 29 IN
MATERIAL IS TO BE PENETRATED TO A DEPTH OF 6 FT
ROOTER WILL LOOSEN A STRIP 9 FT WIDE PER PASS
TRACTOR SPEED - 1.4 MPH
AREA TO BE ROOTED IS 1000 FT x 90 FT
EFFICIENCY FACTOR - .80

DETERMINE: TIME REQUIRED TO ROOT AREA

STEP 1 DETERMINE NUMBER OF PASSES NECESSARY

$$\frac{\text{WIDTH OF AREA}}{\text{WIDTH OF STRIP LOOSENED PER PASS}} = \frac{90\text{ FT}}{9\text{ FT}} = 10\text{ PASSES}$$

$$\frac{\text{DEPTH OF REQUIRED PENETRATION}}{\text{PENETRATION PER PASS}} = \frac{6 \times 12}{29} = 2.5\ (3\text{ PASSES})$$

TOTAL NUMBER OF PASSES = 3 x 10 = 30 PASSES

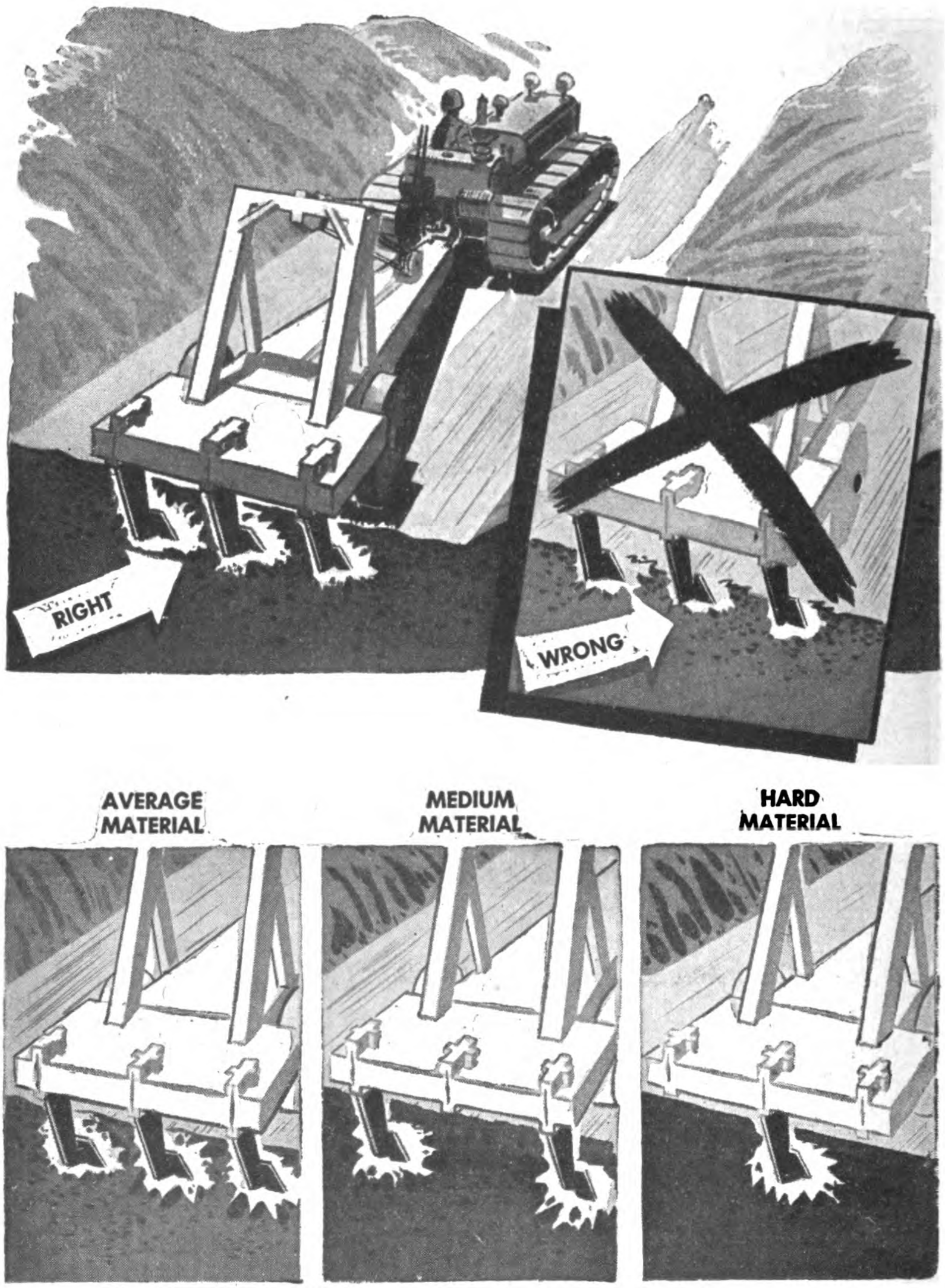
STEP 2 DETERMINE TOTAL DISTANCE TO BE TRAVELED
TOTAL DISTANCE = NUMBER OF PASSES x LENGTH OF PASS = 30 x 1000
= 30,000 FT

STEP 3 SOLVE FOR TOTAL TIME REQUIRED

$$\text{TIME} = \frac{\text{DISTANCE}}{\text{RATE}} = \frac{\overset{\text{(DIST)}}{30{,}000}}{\underset{\text{MPH}}{1.4} \times \underset{\text{FT/MILE}}{5{,}280} \times .80} = 5\text{ HR}$$

Figure 114. Example problem showing method of estimating number of rooter and tractor hours required. When rooter is not operating, tractor is available for other work.

USE 3, 2, OR 1 TEETH FOR MAXIMUM PENETRATION



1 IN AVERAGE MATERIAL USE THREE TEETH FOR FULL BREAKAGE

2 IF SHANKS WILL NOT DIG ➡ ➡ ➚

3 REMOVE CENTER SHANK TO REDUCE DIGGING RESISTANCE

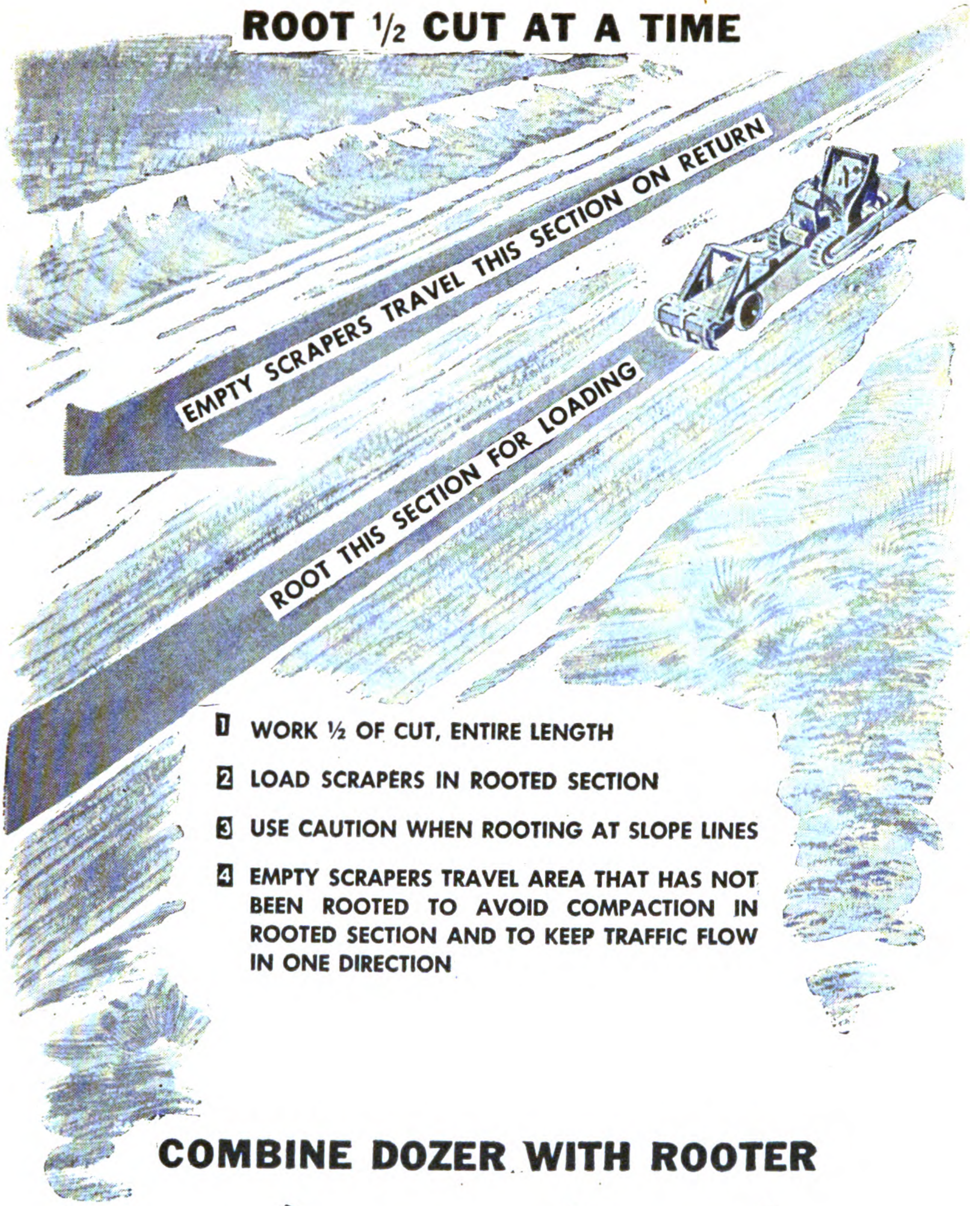
4 IF SHANKS WILL NOT DIG ➡ ➡ ➚

5 REMOVE OUTER SHANKS AND INSTALL CENTER TOOTH

6 WHEN USING ONE SHANK ALWAYS PLACE IN CENTER

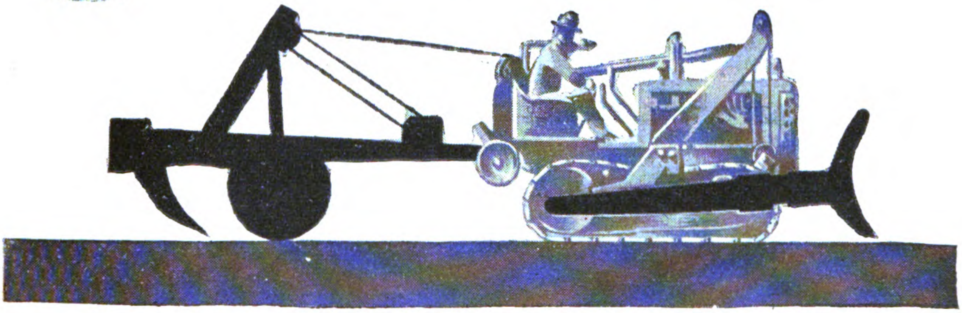
Figure 115. Use the proper number of teeth for maximum penetration.

ROOT 1/2 CUT AT A TIME



1. WORK 1/2 OF CUT, ENTIRE LENGTH
2. LOAD SCRAPERS IN ROOTED SECTION
3. USE CAUTION WHEN ROOTING AT SLOPE LINES
4. EMPTY SCRAPERS TRAVEL AREA THAT HAS NOT BEEN ROOTED TO AVOID COMPACTION IN ROOTED SECTION AND TO KEEP TRAFFIC FLOW IN ONE DIRECTION

COMBINE DOZER WITH ROOTER



BETWEEN ROOTER WORK USE DOZER TO CLEAN UP CUT AND TRIM SLOPES TO UTILIZE FULL TIME OF TRACTOR

Figure 116. Root a complete section before scrapers begin work.

(*b*) When rooted material is to be loaded in scrapers, rooter work in a given area should be complete before scrapers begin work (fig. 116).

(*c*) A tractor-dozer should be used to tow the rooter since it can be used for dozer operations when the rooter is idle. The dozer can usually be employed full time in the immediate vicinity of rooter operations (fig. 116).

(4) *Special techniques.* See figures 117, 118, 119 for proper method of cutting roots, breaking concrete, and removing boulders.

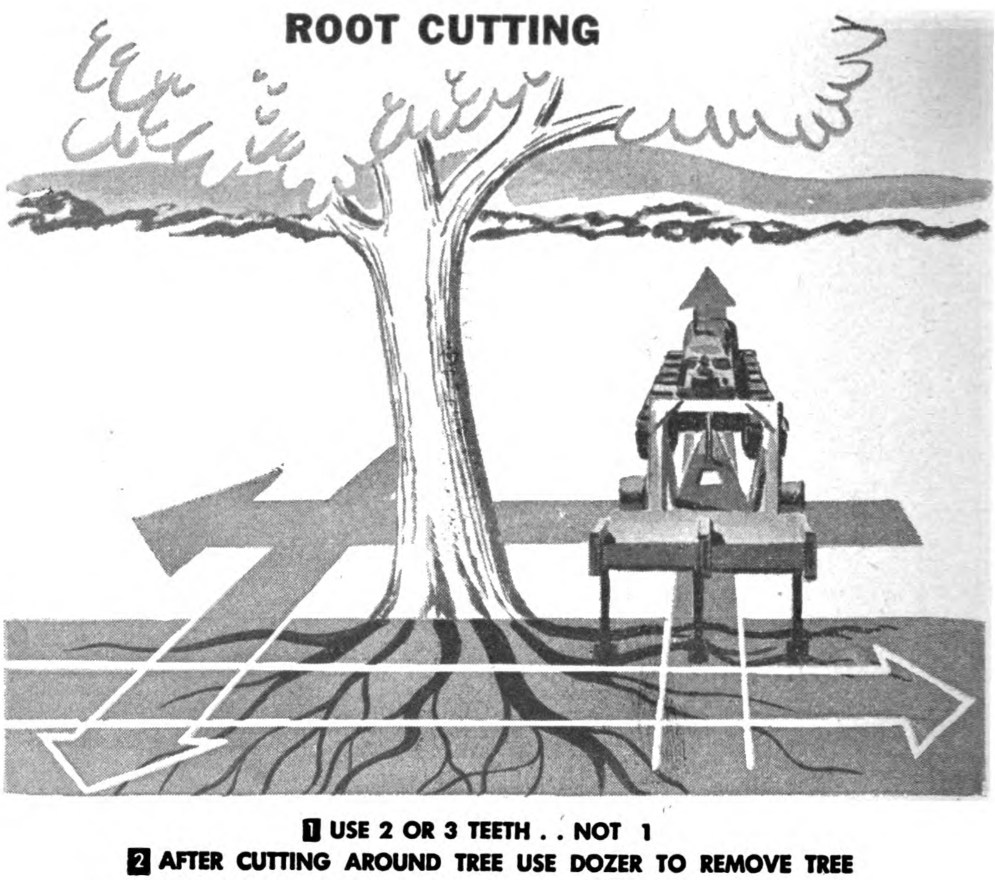
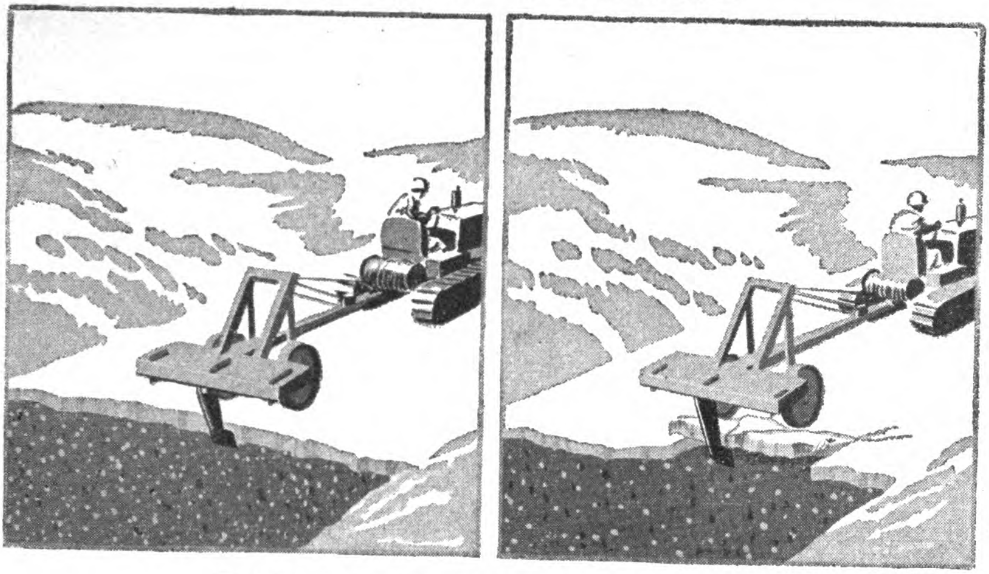


Figure 117. Method of cutting roots.

b. Plows. (1) *Use.* Plows are used primarily on new airdrome and roadway sites to plow out grass, weeds and small brush, and to cut and plow out roots. They are also used to loosen earth to be mixed with stabilizing material. Plows are not effective in consolidated or rocky soils.

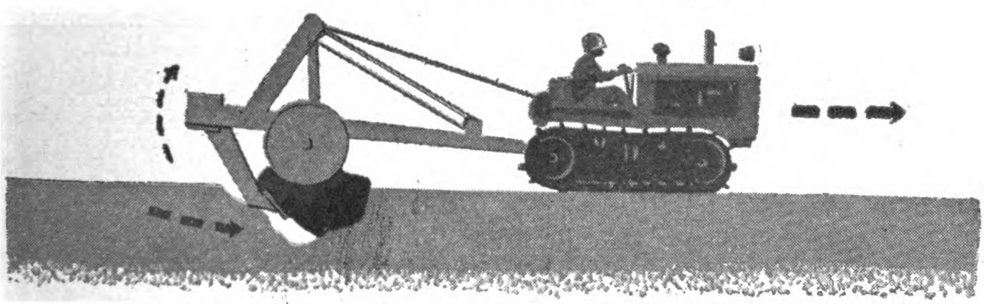
BREAKING CONCRETE



1 HOOK TOOTH UNDER EDGE OF CONCRETE
2 DO NOT BREAK BY FORWARD MOVEMENT OF TRACTOR - TRACKS WILL SLIP
3 LIFT TOOTH TO BREAK CONCRETE
4 MOVE TRACTOR FORWARD AS SLAB BREAKS AND REPEAT

Figure 118. Method of breaking concrete.

REMOVING BOULDERS



1 USE CENTER SHANK ONLY
2 START TOOTH DIGGING FOR FULL PENETRATION TO HOOK OBJECT AS DEEP AS POSSIBLE
3 WHEELS STRADDLE BOULDER
4 HOOK TOOTH, LIFT, AND MOVE FORWARD

Figure 119. Method of removing boulders.

(2) *Estimating work output.* Work output can be estimated on the basis of the following formula.

$$O = \frac{5280 \times S \times W \times E}{9}$$

Where: O = Work output in sq. yd. per hour.
S = Tractor speed in miles per hour.
W = Cutting width in feet.
E = Efficiency factor.

Example: $S = 1.4$ mph
$W = 1.33$ ft.
$E = .80$

$$O = \frac{5280 \times S \times W \times E}{9}$$

$$O = \frac{5280 \times 1.4 \times 1.33 \times .80}{9} = 876 \text{ sq. yd. per hr.}$$

c. Cultivators. (1) *Use.* Chisel-tooth cultivators are used in soil stabilization operations to loosen subgrade material and to mix aggregate and bituminous material with soil. They are also effective in loosening light, crusted surfaces of gravel and earth roads during maintenance operations. Cultivators do not operate effectively in consolidated or rocky soil.

(2) *Estimating work output.* Work output can be estimated by the formula shown in paragraph 2b (2).

Example: $S = 1.4$ mph
$W = 7.5$ feet
$E = 0.80$

$$O = \frac{5280 \times 1.4 \times 7.5 \times 0.80}{9} = 4{,}917 \text{ sq. yd. per hr.}$$

d. Harrows. (1) *Use.* (*a*) Disc harrows are used with plows and cultivators to prepare soil for stabilization. They can break surface crust, loosen and pulverize the soil, and aid in eliminating weeds and grass. Harrows do not work effectively in consolidated or rocky soils, or in wet clays.

(*b*) Spike-tooth harrows are towed behind the disc harrow, disc plow, or chisel-tooth cultivator to break up small clods as they are brought to the surface.

(2) *Estimating work output.* Work output can be estimated by the formula shown in paragraph 49b (2):

Example: $S = 1.4$ mph
W = 8 feet
$E = 0.80$

$$O = \frac{5280 \times 1.4 \times 8 \times 0.80}{9} = 5{,}250 \text{ sq. yd. per hr.}$$

e. Rotary-tiller mixers. (1) *Use.* Rotary-tiller mixers are used in soil-stabilizing operations to mix soil with cement, asphalt, and other stabilizing materials. For most efficient use, the soil should first be partially pulverized by plows, harrows, and cultivators. To prevent damage to rotors, rocks over 4 inches in diameter should be removed before starting operation.

(2) *Estimating work output.* Work output can be estimated by the formula shown in paragraph 49*b* (2).

Example: $S = 1.4$ mph for depth of spread (6 in.)
$W = 4$ ft.
$E = 0.80$

$$O = \frac{5{,}280 \times 1.4 \times 4 \times 0.80}{9} = 2{,}625 \text{ sq. yd. per hr.}$$

Section IX. AIR COMPRESSORS AND PNEUMATIC TOOLS

50. PHYSICAL CHARACTERISTICS. See table XXVII for data on dimensions, weights, operating speeds, and capacities of air compressors, and table XXVIII for data on pneumatic tools.

Table XXVII. Dimensions, weights, operating speeds, and capacities of air compressors

Equipment	Over-all dimensions			Weight (lb.)	Remarks
	Length (inches)	Width (inches)	Height (inches)		
Compressor, air, trailer-mounted, steel wheels, Diesel-engine-driven, 315-cfm.	153	63	89	8,040	Towing speed—10 mph.
Compressor, air, truck-mounted, gasoline-engine-driven, 105-cfm.	254	90	93	14,300	Road speed—45 mph (max.)
Compressor, air, portable, gasoline-engine-driven, 16-cfm.	36	26¼	31½	225	

Table XXVIII. Weight and air required to operate pneumatic tools

Type of tool	Required air (cfm @ 90 psi)	Weight (pounds)
Paving breaker	.65	87½
Rock drill	88	59
Clay spade	32	25½
Nail driver	32	25
Backfill tamper	30	30
Steel drill	80	28
Wood auger	41	31
Circular saw	55	34
Timber saw	90	80
Concrete vibrator	30	24
Portable grinder	85	60
Sump pump	70	51

51. USE OF COMPRESSORS AND PNEUMATIC TOOLS. a. Compressors. Compressors are used to power the pneumatic tools listed in table XXVIII.

b. Pneumatic tools. The following tools powered by air compressors are used in road and airport construction:

(1) *Paving breaker.* Used to cut asphalt or concrete paving, and to demolish concrete foundations, retaining walls, culverts, and floors.

(2) *Rock drill.* Used in rock excavations and quarry work to drill holes for blasting charges.

(3) *Clay spade.* Used to facilitate hand digging or machine excavation in stiff clay, hard sand, or gravel.

(4) *Backfill tamper.* Used to compact earth backfill around culverts and fill material under road patches.

(5) *Timber saw.* An air-operated chain saw used in clearing and in culvert construction.

(6) *Concrete vibrator.* Used to compact concrete and to force sand and cement to form and finish surfaces. This provides smooth, workable surfaces. Also helps eliminate air bubbles and reduces time required to puddle by hand.

(7) *Sump pump.* Used to pump water out of excavations and bomb and shell craters, and to pump water into backfill material around culverts to help compact the soil.

52. WORK OUTPUT OF PNEUMATIC TOOLS. Table XXIX lists the work output of some of the pneumatic tools listed in table XXVIII.

Table XXIX. Work output of pneumatic tools

Pneumatic tool	Work output
Paving breaker, (1 operator)	150 square feet of 6-inch asphalt or concrete paving broken up in a 10-hour day.
Rock drill, (1 operator)	80 linear feet of 1-inch holes in hard rock per 10-hour day.
Clay spade, (1 operator)	12 cubic yards of tough clay can be loosened for shovel excavation in a 10-hour day.
Timber saw, (2 operators)	Will cut 16-inch pine logs in 2 minutes. Will cut lumber up to 24 inches thick.
Concrete vibrator, (1 or 2 operators)	Effective in concrete up to 30 inches thick with a slump of 2½ inches or more.
Sump pump, (1 operator)	175 gpm at 25-foot head.

53. SUPERVISION FOR MAXIMUM WORK OUTPUT. Supervisors responsible for obtaining maximum pneumatic-tool efficiency should keep the following considerations in mind.

a. Compressor. (1) Keep compressor as level as possible.

(2) Place compressor as near tools as possible to cut down airline length.

(3) Never overload compressor by using too many tools. Overloaded compressors will overheat, causing tools to function improperly and under capacity. Compressors will be overloaded when the total required air (table XXVIII) of all the attached tools exceeds the rated capacity of the compressor (table XXVII).

(4) Make continuous lubrication and first echelon maintenance checks in accordance with Technical Manuals and lubrication charts. It is especially important to drain all condensed water from the compressor and to keep all valves carefully set.

b. Pneumatic tools. (1) *Paving breaker.* (*a*) Use only correct size of steel and keep steel point sharp.

(*b*) Operate breakers in tandem. This keeps pavement under constant load and speeds work.

(*c*) Take only small bites (4 to 8 inches back of working face) and break out small pieces.

(*d*) Keep all nuts tight and check air-hose to paving-breaker connection frequently to make sure no air is escaping.

(*e*) Be sure operators merely guide paving breakers. They should be instructed not to ride or lean on them.

(2) *Rock drill.* (*a*) Keep drill steel sharp. Never try to sharpen drills on the job; take them to a shop.

(*b*) Never use worn chucks.

(*c*) Keep all nuts and hose connections tight.

(*d*) Wherever possible, drill holes as close to vertical as possible to utilize weight of drill machine.

(*e*) When air through drill steel is not sufficient to keep drill hole clean, use an air line to blow out the hole before it becomes clogged.

(3) *Clay spade.* (*a*) Use only for trimming and loosening earth, not as a pry.

(*b*) Use only on earth, gravel, and hard clay, *not* on pavement or rock.

(4) *Backfill tamper.* (*a*) Keep all nuts and hose connections tight.

(*b*) When tamping loose earth, wrap tamping head in burlap.

(*c*) When tamping gravel, leave tamping head unwrapped.

(*d*) Keep tamper moving across fill; never leave tamper in one position.

(*e*) When tamping around culverts, tamp 2- to 3-inch layers around them. In no case allow tamping head to touch side of culvert.

(5) *Timber saw.* (*a*) Keep chain at proper tension.

(*b*) Never force saw through wood.

(*c*) When cutting large trees, use wedges to keep saw from binding.

(*d*) Use two men to man saw efficiently.

(6) *Concrete vibrator.* (*a*) Keep vibrator moving at all times. Do not allow it to hit forms or reinforcing steel.

(*b*) Use two men on each vibrator: one to man power unit, other to keep head moving.

(*c*) Vibrate concrete thoroughly and float vibrator at surface. This

brings cement and sand to top and produces workable material for finishing machine.

(7) *Sump pump.* (*a*) In cold weather, put alcohol in the manifold. (*b*) Keep suction end away from mud bottoms.

(*c*) Keep sticks away from suction end. Clean suction end every 2 operating hours.

Section X. CRUSHING, WASHING, SCREENING, AND AUXILIARY QUARRY AND GRAVEL-PIT EQUIPMENT

54. PHYSICAL CHARACTERISTICS. See table XXX for data on dimensions, weights, operating speed, and fuel consumption of quarry and gravel-pit equipment.

Table XXX. Dimensions, weights, operating speeds, and fuel consumption of crushing, washing, screening, and auxiliary quarry and gravel-site equipment

Equipment	Over-all working dimensions			Weight	Gasoline engine	Fuel consumption	Towing speed (max)	Miscellaneous data				Shipping data			
	Length	Width	Height					Conveyer belt							
Conveyers	Ft	Ft	Ft	Pounds	hp	Gallons per hour	mph	Length (ft)	Width (in)	Material	Belt speed	Number of crates	Boxed weight (pounds)	Total cubage (cu ft)	Number of flatcars reqd
Belt-transfer conveyer, gasoline-engine-driven, 30-inch by 50-foot high mast.	50	8.9	17	13,500	19	1.85	7	100	30	Rubber	300 to 400 (fpm)	1	13,500	576	⅓
Belt-transfer conveyer, gasoline-engine-driven, 30-inch by 35-foot low mast.	39	8.1	13.3	11,150	19	1.85	7	70	30	Rubber	300 to 400 (fpm)	1	12,500	576	⅓
Belt-transfer conveyer, gasoline-engine-driven, 30-inch by 50-foot low mast.	54	8.9	13.3	12,175	19	1.85	7	100	30	Rubber	Rock conveyer (300 rpm) Sand conveyer (400 rpm)	1	13,500	576	⅓

Table XXX. Dimensions, weights, operating speeds, and fuel consumption of crushing, washing, screening, and auxiliary quarry and gravel-site equipment—Continued

Equipment	Over-all working dimensions			Working weight	Gasoline engine	Fuel consumption	Towing speed (max)	Equipment data						Shipping data			
								Conveyers		Crusher							
	Length	Width	Height					Number	Size	Type	Size	Output	Mounting	Number of boxes	Shipping Weights	Cubage	Number of flatcars reqd
Crushers	Ft	Ft	Ft	Pounds	hp	Gallons per hour	mph					Tons per hour			Pounds	cu ft	
Jaw-type, gasoline-engine-driven, 30- by 42-inch.	46.5	18	22.2	117,465	156	12.5	7	2	30-inch by 32-feet	Jaw	30 by 42 inches	200 to 400	Crawlers	17 (pieces)	117,465	8,500	1
Jaw-type, trailer-mounted, 7-cubic-yard.	9.3	5	6.5	6,200	28.5	2.5	15	None		Jaw	10 by 16 inches	(7 cu yd)	Steel wheels	1	8,582	294	⅛
Roll-type, gasoline-engine-driven, 54- by 24-inch.	43.3	9.7	17.3	78,835	156	14.0	7	2	30-inch by 40-feet 30-inch by 40-feet	Roller	Diameter 54 inches Width 24 inches	100–190	Crawlers	7 (pieces)	78,835	6,521	1
Roll-type, gasoline-engine-driven 40- by 22-inch.	29.9	8.7	13	53,235	143	12.5	7	4	Width 30 inches Length 40 feet 12.3 feet 8 feet 9 feet	Roller	Diameter 40 inches Width 22 inches	40–140	Steel wheels	3	53,335	3,980	1

Table XXX. *Dimensions, weights, operating speeds, and fuel consumption of crushing, washing, screening, and auxiliary quarry and gravel-site equipment—Continued*

Equipment	Over-all working dimensions			Working Weight	Gasoline engine	Fuel consumption	Towing speed	Equipment data						Shipping data			
								Conveyers									
	Length	Width	Height					Number	Size	Crusher size	Output	Pump	Mounting	Number of boxes	Shipping weight	Cubage	Number of flatcars
Crushing, screening, and washing plant.	Ft	Ft	Ft	Pounds	hp	Gallons per hour	mph				Tons per hour	gpm			Pounds	Cu ft	
Roller type, 40-in-dia by 22-in.	48	10	19	70,955	Power unit, trailer-mounted			3	Width 30 in Length 21 ft 25 ft 50 ft	Diameter 40-in Width 22 in	40 to 140	1,000 (80-ft head)	Crawler	8 (pieces)	70,955	7,844	1
					120 to 140	12.5	7										
Crushing and screening plant.																	
Jaw-type unit, 15 tons per hour with 18-cu-yd steel bin.	35.7	11.5	24	37,545	45	Not listed	10 to 15	1 Elevator type	6- by 10-in buckets	10- by 20-in (jaw crusher)	5 to 46	None	4-steel wheels	6	44,213	2,076	¼
2-unit, jaw- and-roller crusher, 25 cu yd per hour output.	32.5	8	10.5	32,070	65	5.5	20	1	Width 18 in Length 18 ft	15- by 24-in (jaw crusher)	25 cu yd	None	2 units, rubber-tired semi-trailers	1	46,345	2,750	½
														1	46,345	2,750	½

Table XXX. Dimensions, weights, operating speeds, and fuel consumption of crushing, washing, screening, and auxiliary quarry and gravel-site equipment—Continued

Equipment	Over-all working dimensions			Working Weight	Gasoline engine	Fuel consumption	Towing speed	Equipment data						Shipping data			
								Conveyors									
	Length	Width	Height					Number	Size	Crusher size	Output	Pump	Mounting	Number of boxes	Shipping weight	Cubage	Number of flatcars
Washing and screening plant.	Ft	Ft	Ft	Pounds	hp	Gallons per hour	mph		Ft		Tons per hour	gpm			Pounds	Cu ft	
75 tons per hour sand and gravel washing and screening plant.	58	8	13	47,125	74	7.4	20	3	Width 2 Length 28.5 5.2 Width 2.5 Length 3.5	None	75	Required as add equip 700 gpm at (50-ft head)	Rubber-tired semi-trailers	7	51,700	3,187	1

Table XXX. Contd

Reciprocating-plate conveyer feeder

Used when jaw crusher is not used

Capacity	400 tons per hour
Drive	Chain
Horsepower required	5 hp
Conveyer:	
Width	30 inches
Length	21 feet
Working dimensions:	
Length	6 feet
Width	6 feet
Height	7 feet
Hopper capacity	2⅓ cubic yards
Working weight:	
Hopper	1,300 pounds
Conveyer	2,600 pounds
Shipping data:	
Boxes	2
Weight	5,310 pounds
Cubage	758 cubic feet
Flatcars	⅓

Centrifugal pump, gasoline-engine-driven

Rating:	
1-pump =	1,000 gpm at 80-foot head
2-pumps (in series) =	1,100 gpm at 150-foot head
Motor	51.3 hp at 1500 rpm
Fuel consumption	6.0 gallons per hour
Mounting	4 steel wheels
Towing speed	7 mph
Working dimensions:	
Length	13 feet
Width	7.5 feet
Height	10.1 feet
Working weight	7,250 pounds
Shipping data:	
Pieces	2
Weight	7,250 pounds
Cubage	1,362 cubic feet
Flatcars	⅓

Scrubber and washer, paddle-type, gasoline-engine-driven

Rating	80 to 100 tons per hour
Motor	143 hp
Fuel consumption	10 gallons per hour
Mounting	6 steel wheels
Towing speed	7 mph
Working dimensions:	
Length	32 feet
Width	12 feet
Height	10 feet
Working weight	51,050 pounds
Shipping data:	
Pieces	2
Weight	51,050 pounds
Cubage	5,093 cubic feet
Flatcars	1

Dehydrator

Power	Chain drive from roll crusher
Mounting	Steel wheels
Towing speed	7 mph
Screw flight:	
Diameter	22 inches
Length	20 feet
Water consumption	600 gpm
Working dimensions:	
Length	29.8 feet
Width	8 feet
Height	10.9 feet
Working weight	18,110 pounds
Shipping data:	
Boxes	2
Weight	18,325 pounds
Cubage	1,475 cubic feet
Flatcars	1

55. USE AND CAPACITIES OF QUARRY AND GRAVEL-PIT EQUIPMENT. a. Types of plants and use. (1) *Fourteen-unit pioneer crushing, screening, and washing plant.* This plant has 14 units which process quarry rock or gravel in either washing or dry operations. The approximate plant capacity is 150 tons per hour (tph) of washed, crushed rock passing a 1¼-inch-square opening. Quarry material is delivered by trucks and fed into the machine over a truck ramp or by power shovels.

The plant consists of the units listed below:

(*a*) Crusher, jaw-type, gasoline-engine-driven, crawler-mounted, 30- by-42-inch opening, 200 to 400 tph (56–A).

(*b*) Crusher, roll-type, gasoline-engine-driven, crawler-mounted, 54-inch diameter by 24-inch face rolls, 100 to 190 tph (54–VA).

(*c*) Conveyer, belt, transfer, gasoline-engine-driven, 30-inch width, 50-foot, high mast.

(*d*) Crusher, screen and washer, roll-type, belt-driven, crawler-mounted, 40-inch diameter by 24-inch face, 40 to 140 tph (300–WA).

(*e*) Power unit, gasoline-engine-driven, trailer-mounted (four steel wheels), 120 to 140 hp.

(*f*) Crusher, roll-type, gasoline-engine-driven, trailer-mounted (six steel wheels), 40-inch diameter by 22-inch face rolls, 40 to 140 tph.

(*g*) Conveyer, belt, transfer, gasoline-engine-driven, 30-inch width, 35-foot, low mast.

(*h*) Dehydrator, sand, twin-screw-feed, chain-driven, trailer-mounted (four steel wheels), 40 to 60 tph.

(*i*) Feeder, reciprocating-plate, chain-driven, 30-inch-wide, with 30-inch by 21-foot belt conveyer.

(*j*) Scrubber and washer, paddle-type, gasoline-engine-driven, trailer-mounted (six steel wheels), 80 to 100 tph, with 7-foot by 20-foot tank.

(*k*) Pump, centrifugal, gasoline-engine-driven, trailer-mounted, 6-inch discharge, 1,000 gpm at 80-foot head.

(*l*) Conveyer, belt, transfer, gasoline-engine-driven, 30-inch by 50-foot, low mast, 300 fpm.

(*m*) Conveyer, belt, transfer, gasoline-engine-driven, 30-inch by 50-foot, low mast, 400 fpm.

(*n*) Piping equipment for washers, dehydrator, and crushers.

(2) *Ten-unit pioneer crushing, screening, and washing plant.* This plant processes pit gravel in either washing or dry operations. The approximate plant capacity is 100 tph of washed, crushed gravel passing a ¾-inch screen opening. Gravel is delivered by trucks and fed into the machine over a truck ramp or by power shovels.

The plant consists of the units listed below:

(*a*) Feeder, reciprocating-plate, chain-driven, 30-inch wide, with 30-inch by 21-foot belt conveyer.

(*b*) Crusher, roll-type, gasoline-engine-driven, crawler-mounted, 54-inch diameter by 22-inch face rolls, 100 to 190 tph.

(*c*) Conveyer, belt, transfer, gasoline-engine-driven, 30-inch by 50-foot, high mast.

(*d*) Crusher, screen and washer, roll-type, belt-driven, crawler-mounted, 40-inch diameter by 22-inch face rolls, 40 to 140 tph.

(*e*) Power unit, gasoline-engine-driven, trailer-mounted (four steel wheels), 120 to 140 hp.

(*f*) Dehydrator, sand, twin-screw-feed. chain-driven, trailer-mounted (four steel wheels), 40 to 60 tph.

(*g*) Conveyer, belt, transfer, gasoline-engine-driven, 30-inch by 50-foot, low mast, 400 fpm.

(*h*) Conveyer, belt, transfer, gasoline-engine-driven, 30-inch by 50-foot, low mast, 300 fpm.

(*i*) Pump, centrifugal, gasoline-engine-driven, trailer-mounted, 6-inch discharge, 1,000 gpm at 80-foot head.

(*j*) Piping equipment for washer, dehydrator, and crusher.

(3) *Pioneer sand and gravel washing and screening plant.* (*a*) This plant produces washed sand or gravel for concrete-aggregate or bituminous surfacing. It is a self-contained unit mounted on a rubber-tired trailer and consists of a gasoline-engine power unit, receiving hopper and reciprocating-plate feeder, vibrator screen, twin-screw dehydrator, belt-type feeder conveyer, and sand and gravel delivery conveyers. The approximate capacity of the plant is 75 tons per hour.

(*b*) While this unit can process and load sand alone, trucks and power shovels are required when loading unwashed gravel and delivering washed sand and gravel. In addition, a 700-gpm, 50-foot-head pump and piping equipment are needed.

(4) *Two-unit 25 cubic yard per hour rock crushing and screening plant.* (*a*) This plant is used in quarries to crush rocks with dimensions less than 13 by 22 inches. It can be adjusted to produce fragments 1/4 to 2 1/2 inches in size. Its approximate capacity is 25 cubic yards per hour. This plant does not wash the aggregate. Supplementary equipment is required to load and deliver the aggregate.

(*b*) The plant consists of the following two units:

1. *Jaw crusher.* Used to crush large material to roll-crusher maximum size.
2. *Roll crusher.* Used to crush material from jaw crusher to 1- to 2 1/2-inch size and to screen the crushed rock.

(5) *Jaw-type rock crusher (7 cubic yards per hour).* This trailer-mounted crushing and screening plant is a self-contained plant to crush rocks up to 6 by 10 inches in size to 1/2- to 1 1/2-inch rock. The plant windrows rock on the surface where it can be spread by a grader.

(6) *Crushing and screening plant (15 tph).* This plant is designed to crush and screen rock from gravel pits or quarries. Material passing through the screen is elevated to a bin for storage or loading into trucks.

(7) *Batching plant.* Batching plants are used to store, proportion, and dump-deliver bituminous and concrete aggregate. The three-bin 105-ton capacity batcher is the most common size used.

b. Capacity. See table XXXI for output of quarry and gravel-pit equipment.

Table XXXI. Output capacity of gravel-pit and quarry equipment

Plant	Aggregate Size (# = sieve size)	Average Output (Tons per hour)
Pioneer (10- or 14-unit plant) crushing, screening, and washing.	¾″ to #4 1″ to #4 1½″ to ⅜″ 2″ to #4 2½″ to 1½″ 2″ to 1″	79 123 172 268 174 158
Washing and screening (1-unit plant) sand and gravel.	Up to 2½″	75
Crushing and screening (2-unit plant).	Up to 2½″ Up to 1½″ Up to 1″	24–40 15–27 12–20
Jaw crusher, trailer-mounted.	Up to 1½″ Up to ½″	6–11 4–6
Crushing and screening plant, trailer-mounted. (Includes 18-cubic-yard steel storage bin).	Up to ¾″ 1″ 1½″ 2″ 2½″ 3″	5–9 7–14 11–22 15–24 18–30 33–46

56. SUPERVISION FOR MAXIMUM WORK OUTPUT. Supervisors responsible for obtaining maximum gravel-pit and quarry equipment efficiency should keep the following considerations in mind.

a. Quarry and pit selection. (1) *General.* Quarry and pit selection depends on the following factors:

(2) *Worked quarries.* Wherever possible, worked quarries should be used. Their use cuts down the amount of overburden that must be removed, and it is usually easy to determine the quality, size, and quantity of material that can be obtained. Worked quarries are usually near good haul roads and have auxiliary equipment such as hoppers, construction railroads and cars, and conveyers which can be put to use immediately in setting up and starting quarry operation.

(3) *New quarries.* Where a new quarry must be opened, the type and quantity of material is usually the controlling factor in choice of site. Wherever possible, a site with no overburden should be chosen, thus eliminating time and machinery required for stripping. Where this type of site cannot be found, soundings with earth augers or study of rock or gravel outcrops in existing road cuts or on hillsides will reveal the type of material under the overburden. When the overburden cannot be used, it should be stripped from the quarry and used as fill or wasted.

(4) *Length of haul.* Hauls should be as short as possible.

(5) *Size and gradation of material.* Where size and gradation of materials are specified, it must be determined whether or not the quarry or pit site selected will produce the material. It may be neces-

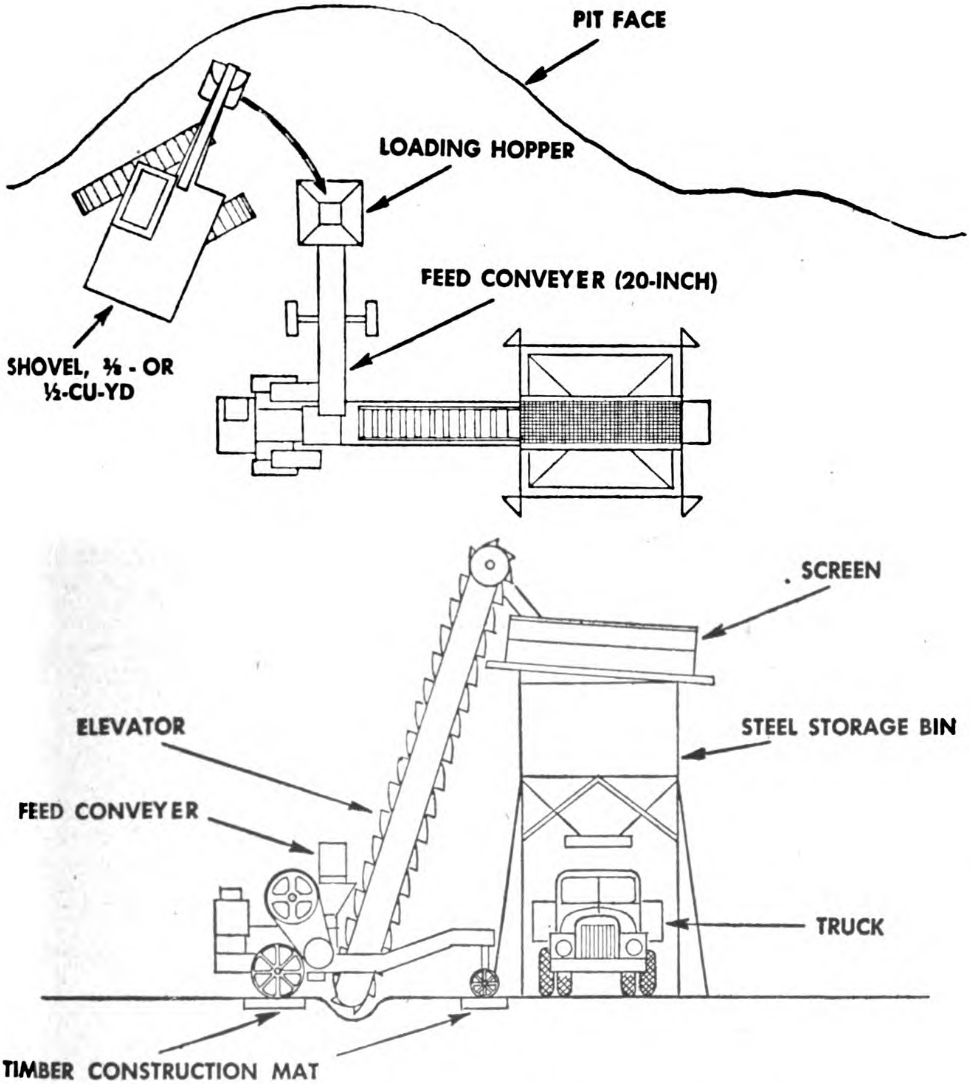


Figure 120. Fifteen-tph crushing and screening plant lay-out.

sary to work two or three pits and mix and size material in a crushing and screening plant to obtain the material specified.

(6) *Washing.* Where washing is required, the quarry or pit should be close to a source of water. Pumping capacity, length of pipe, and elevation of water source and pit equipment limit the distance between the pit and water source. The water source should be able to furnish 1,000 and 2,000 gpm. The rule to remember in washing is that ordinarily it is not possible to run too much water through a washer. The overflow pipes in washers and scrubbers should flow full at all times.

(7) *Size of quarry or pit material.* The maximum size of quarry or pit material must not exceed the crusher dimensions. To keep out large rocks and boulders, a grizzly can be constructed of rails or heavy timber. The rails or timbers are criss-crossed to form a screen that will exclude large boulders or rocks. The grizzly is mounted on the hopper and sloped to make manhandling of large rocks easier.

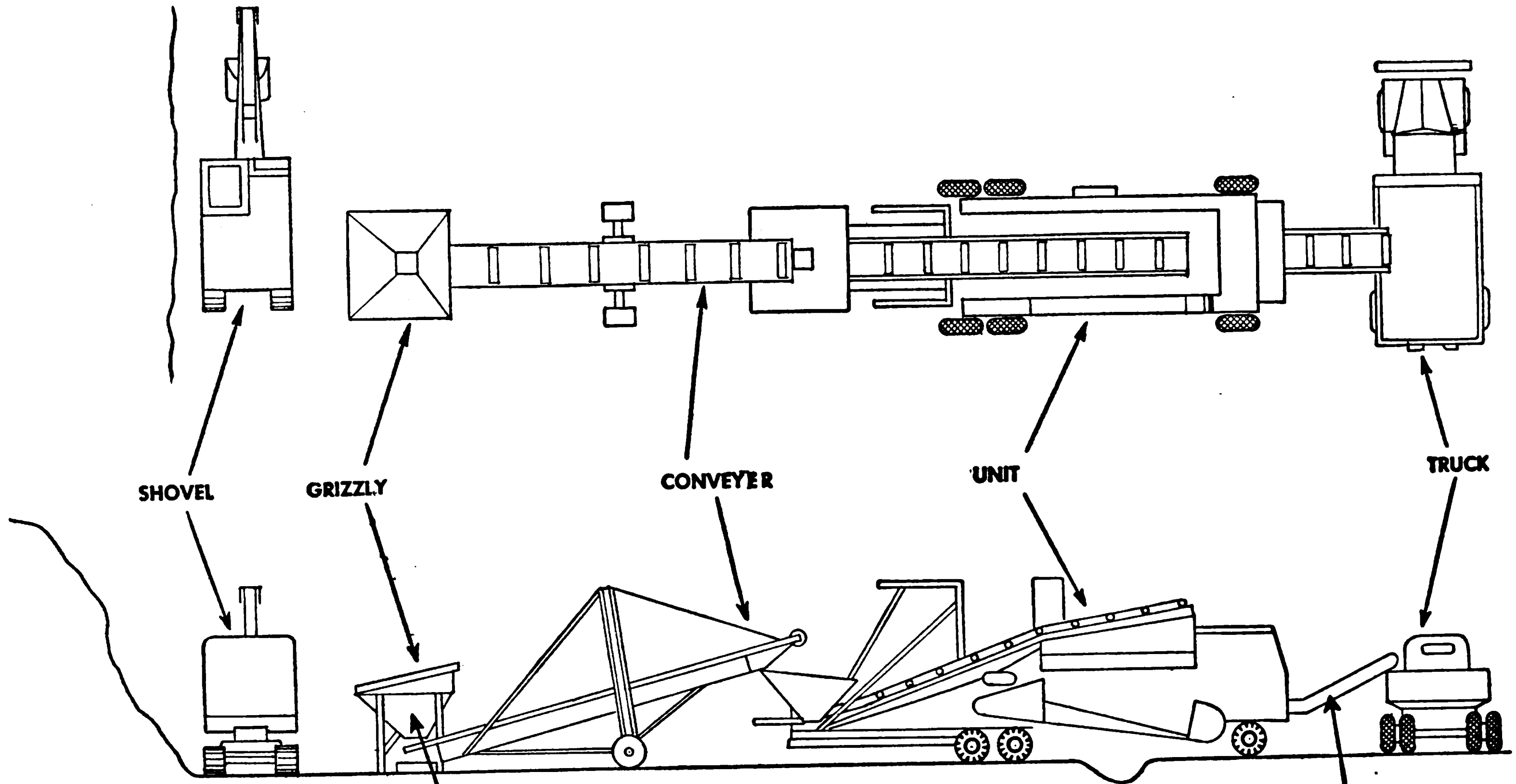


Figure 121. Washing and screening plant layout loading from pit bank.

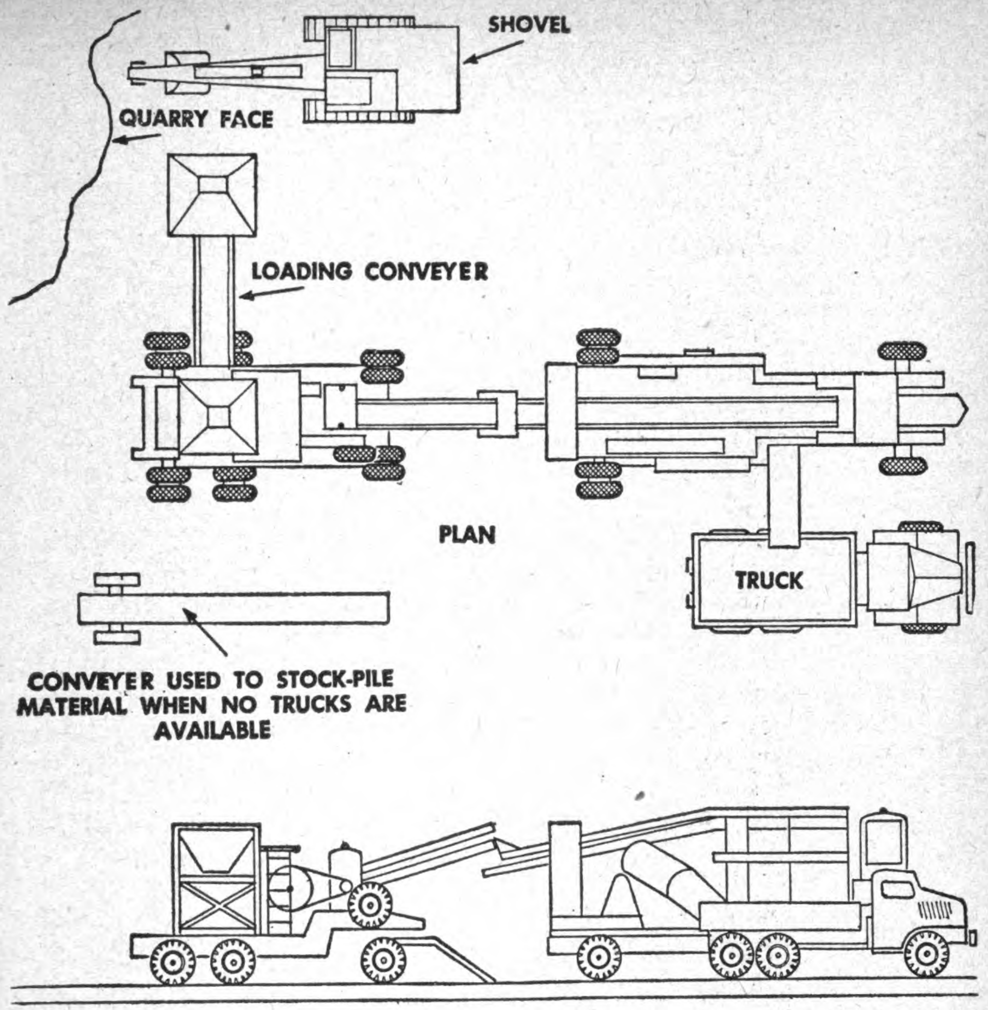


Figure 122. Two-unit crushing and screening plant.

b. Plant lay-out. (1) *Rock crusher (7–cubic yard).* The crusher should be set up over a trap or on a hillside in the quarry. Each hour six to ten 2½–ton truck loads of rock are required to keep the plant operating at full capacity. Two men are required to unload the rock from the truck into the crusher. A wood hopper erected over the crusher facilitates unloading into the crusher.

(2) *Crushing and screening plant (15–tph).* Figure 120 shows a 15–tph crushing and screening plant set up in a quarry. The unit should be as close as possible to the quarry face. The crusher is mounted and blocked on firm footings to keep it level. A haul road should be built under the storage bin to facilitate truck loading. A ⅜– or ½–cubic-yard shovel is used to load the crusher; two or three men to operate the plant; and eight to twelve 2½–ton truck loads per hour are required to haul away the crushed rock.

(3) *Sand and gravel washing and screening plant.* Figure 121 shows a suggested layout for this washing and screening plant with the

unwashed material being taken right from the pit bank. Where pit material is of proper quality, this set-up saves hauling to plant and crushing. A ½- or ¾-cubic-yard shovel is required to load; 4 men to operate; and 30 to 40 truck loads per hour to load, operate, and haul material. While in operation, the unit should be jacked off its rubber tires and blocked securely. The water pump should be mounted on a solid foundation and blocked securely.

(4) *Two-unit crushing and screening plant.* Figure 122 shows the 2-unit plant layout operating close to a pit bank or quarry face. A ½- or ¾-cubic-yard shovel, 5 men, and 20 to 30 truck loads per hour are required to load, operate, and haul material away from the plant. The haul road must be continuous and must be kept clear at all times. When trucks are not available, use a belt conveyer to stock-pile dumped material clear of the haul road and of all machines. While in operation both units must be jacked and securely blocked off the rubber tires.

(5) *Crushing, screening, and washing plants (10- and 14- unit).* (*a*) *General.* These crushing, screening, and washing units can be used in various combinations to handle various size rock and gravel. The equipment supervisor should balance the flow between various size crushers by changing the limit dimensions of crusher rollers and jaws. When washing is not necessary, the pump and washer are not used in the set-ups. Each new quarry or pit requires a new set-up and the number of units necessary to operate them varies with the character of rock at the pit and the specifications for the finished product.

(*b*) *Plant lay-out.* The following are suggested plant lay-outs for washed and unwashed materials in various types of quarries or pits.

1. *Dry-gravel plant.* Figure 123 shows a lay-out for an unwashed dry-gravel plant.

2. *Washed-gravel plant.* Figure 124 shows a lay-out for washed-gravel plant.

3. *Washed-rock plant.* Figure 125 shows a lay-out for washed crushed rock. In this plant, it is especially important to balance flow between crushers to keep equal loads flowing through crushers.

4. *Rock plant for concrete aggregate where plastic clay or shale is present.* Listed below are the units required for a concrete aggregate plant where plastic clay or shale is present in the rock.

Unit 56–A, jaw crusher
Unit 54–VA, roller crusher (intermediate)
Unit 300–WA, washing plant
Unit 300–WA, power unit
Unit 42–VA, roller crusher (fines)
Log washer
Pumps (2) with pipe line
Conveyer, high-mast, 50-foot
Conveyers (two sand and rock, 50-ft, low mast)
Conveyer, 35-foot

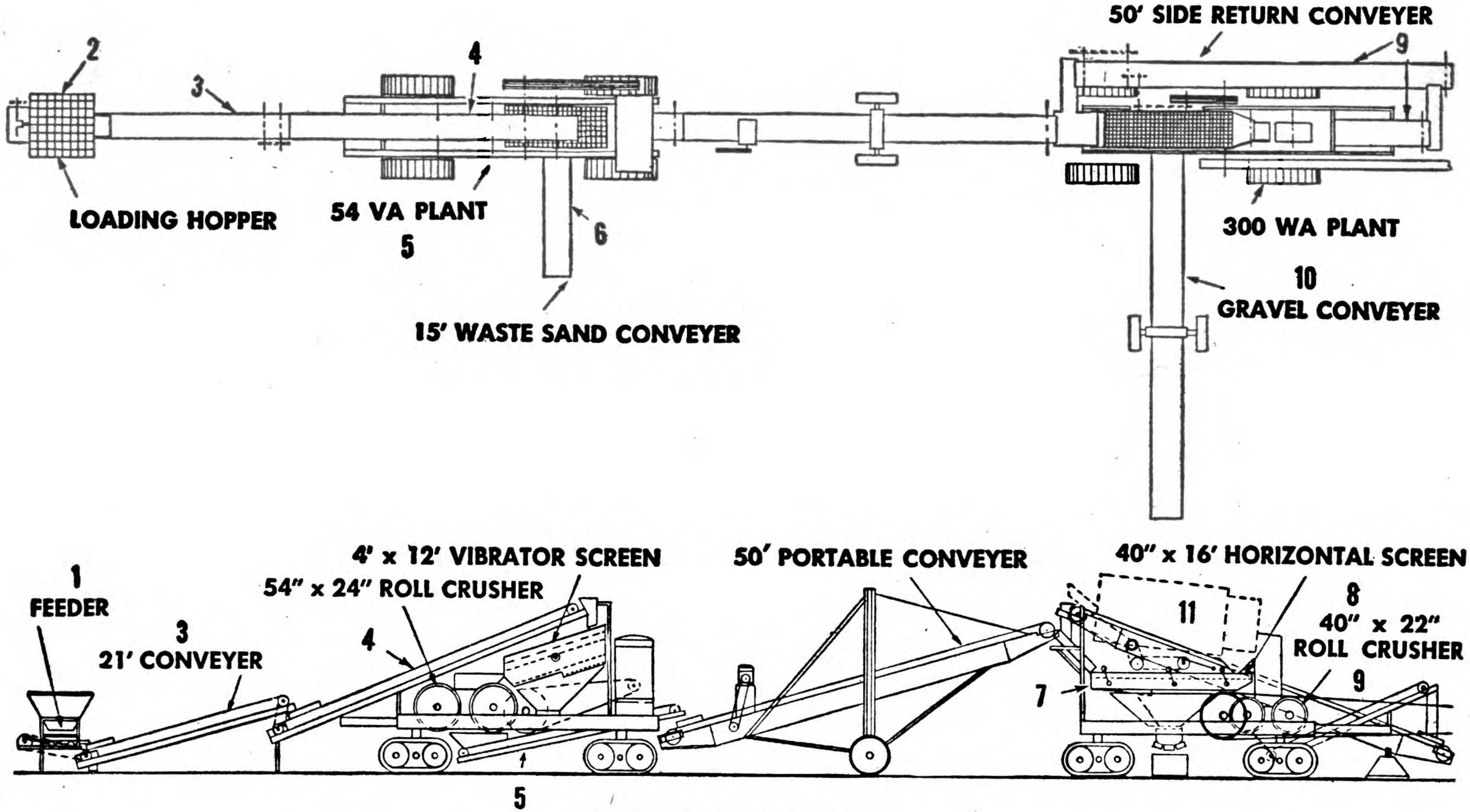


Figure 123. Dry-gravel plant.

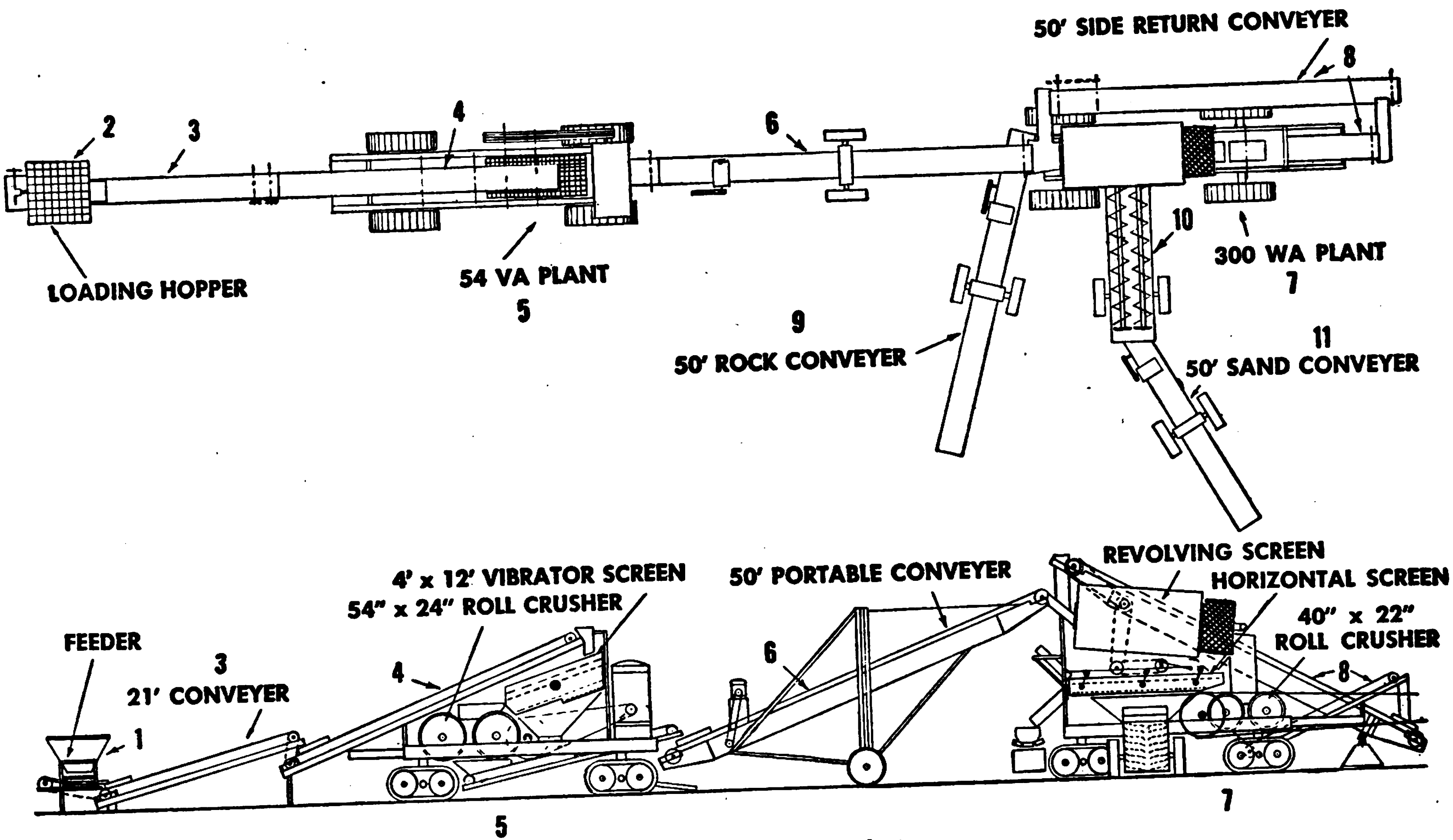


Figure 124. Washed-gravel plant.

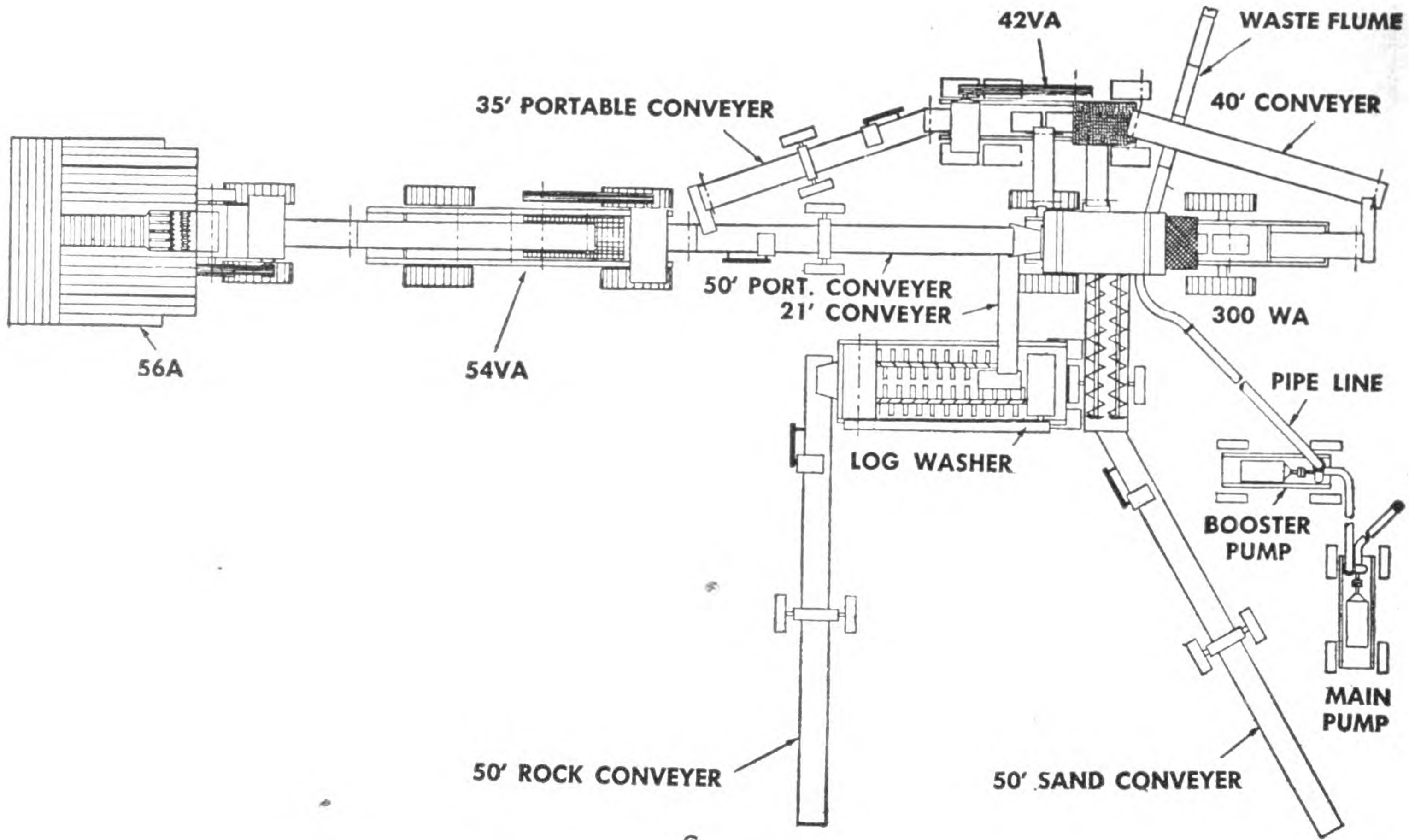


Figure 125. Washed-rock plant layout.

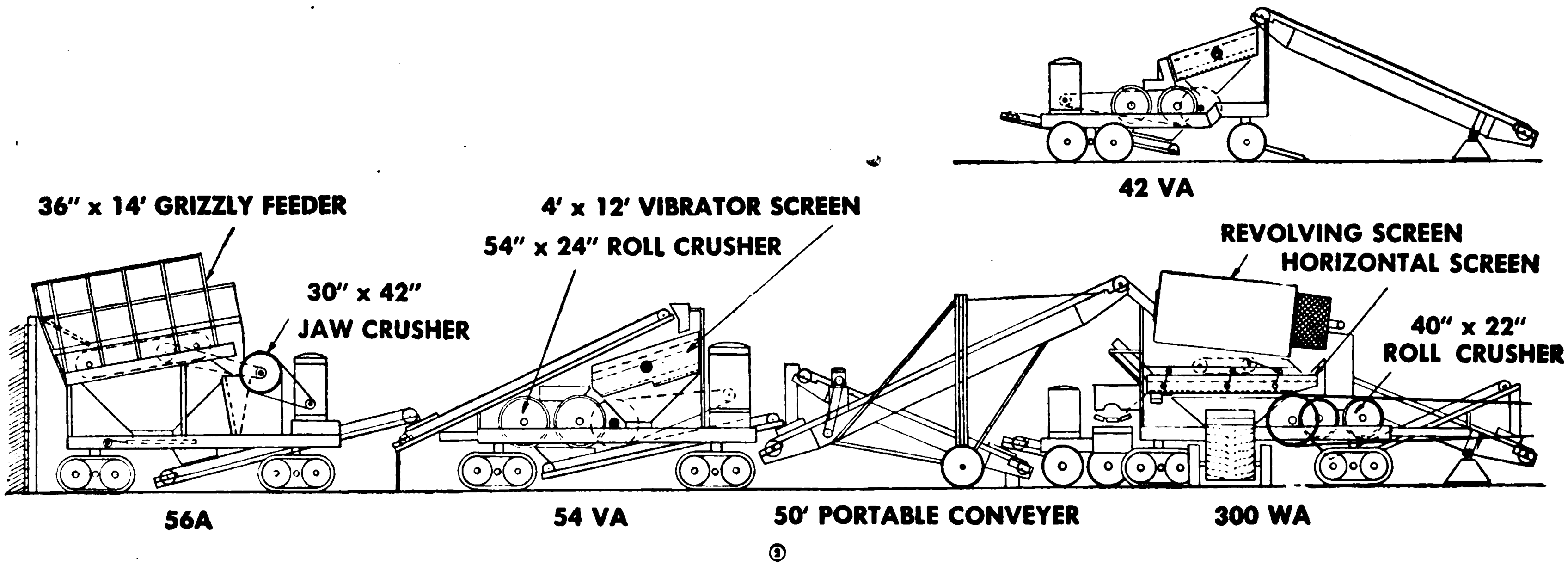


Figure 125. Washed-rock plant layout—Continued.

5. *Gravel-pit operation for concrete aggregate.* Listed below are the units required for a concrete aggregate plant for gravel pits.

Conveyer, 21-foot extension channel frame
Plate feeder, reciprocating, 30-inch, with 21-foot conveyer
Unit 54–VA, roller crusher
Conveyer, high-mast, 50-foot
Unit 300–WA, washing plant
Unit 300–WA, power unit
Screw dehydrator
Pumps (2) with pipe line
Conveyers (two sand and gravel, 50-foot, low mast)

Note. Where rocks over 7 inches are found in considerable quantity and it is desirable to crush them, add 56–A unit. Add log washer if plastic clay or shale is present in final product.

6. *Rock plant for washed dry-bound macadam or base-course material.* Listed below are the units required to produce dry-bound macadam or base-course material. The capacity of the plant (washed material) is listed in table XXXII.

Unit 56–A, jaw crusher
Unit 54–VA, intermediate crushing unit
Unit 300–WA, washing plant
Unit 300–WA, power unit
Conveyer, high-mast, 50-foot
Conveyers (two sand and rock, 50-foot)
Screw dehydrator
Pumps (2) with pipe lines and flumes

Note. Log washer should be used if an excessive amount of clay balls or shale is found.

Table XXXII. Macadam and base-course material output of rock plant

Maximum size (inches)	Tons per hour (tph)
4	198–266
5	222–309
6	275–412
8	344–515

7. *Rock plant for unwashed dry-bound macadam or base-course material.* Listed below are the units required to produce dry-bound macadam or base-course material. The capacity of the plant is listed in table XXXII.

Unit 56–A, jaw crusher
Unit 54–VA, intermediate crushing unit
Unit 300–WA, washing plant with 50-foot return conveyer
Conveyer, high-mast, 50-foot
Conveyers (two sand and rock, 50-foot)
Unit 300–WA, power unit

8. Quarry or gravel-pit plant for crusher-run base-course material. Listed below are the units required to produce crusher-run base-course material. The capacity of this plant is listed in table XXXII.

Unit 56–A, jaw crusher
Unit 54–VA, roller crusher
Conveyer, 50-foot
Conveyer, 15-foot (side delivery)

Note. a. Output of roller crusher 54–VA is listed in table XXXIII.
b. In gravel pits, the jaw crusher may not be required.
c. In gravel pits, a 30-inch reciprocating-plate feeder should be mounted on unit 54–VA.

Table XXXIII. Roller crusher 54–VA output

Maximum size (inches)	Tons per hour (tph)
1¼	115
1½	135
2	182
2½	230
3	270

9. Gravel-pit equipment for bituminous materials. Listed below are the units required to produce bituminous materials from gravel pits. With this plant, 100 percent fractured material can be obtained and any size and grading of aggregate can be obtained. The plant capacity is listed in table XXXI.

Unit 54–VA, roller crusher
Unit 300–WA, crusher and screener and power unit
Conveyer, high-mast, 50-foot
Conveyers, (two), 50-foot
Plate feeder, reciprocating, 30-inch
Channel-frame extensions for unit 54–VA,
15-foot
21-foot

For washed material add:

Unit 300–WA, pumps (2)
Piping, pipe fittings, and flumes
Pontoon and foot valve
Screw dehydrator

10. Quarry equipment for bituminous materials. When operating in a rock quarry, the following equipment is needed in addition to the gravel-pit equipment listed in 9 above.

Unit 56–A, jaw crusher
Log washer

Note. The 30-inch reciprocating-plate feeder can be eliminated when using unit 56–A.

(c) *Foundations.* Plants should be on a heavy reinforced-concrete foundation. Each unit should be placed on slabs 6 to 12 inches thick. Slabs under each machine should be at least 13½ feet wide and 10 feet longer than the wheel base. Where units are spaced 5 or 10 feet apart, one large slab can be poured.

(d) *Loading.* Units can be loaded with a shovel and conveyer or with a shovel, trucks, and a bulkhead loading ramp. (See fig. 126.) The bulkhead ramp should be just high enough to allow the trucks to dump into the jaw crusher.

Figure 126. Bulkhead loading ramp used to load material into jaw crusher.

(6) *Methods of working quarry face.* (a) Quarry faces can be worked efficiently with conveyers. Figure 127 shows the method of using one and two conveyers in working a quarry face. Rock is blasted from the face and cleaned up with a shovel and one conveyer. Then the face is again cut back and cleaned, using a shovel and two conveyers in series.

(b) Gravel pits can be worked efficiently in terraces by *digging in* the hopper loader and stock-piling gravel near it with a scraper. A bulldozer is used to load the stock-piled material into the hopper. (See fig. 128.)

c. Material gradation. Rock is crushed to specified size by controlling the jaw or roller-crusher opening and by screening. Table XXXIV can be used to find the percent of any size rock passed and retained with crusher openings from ¼ to 5 inches.

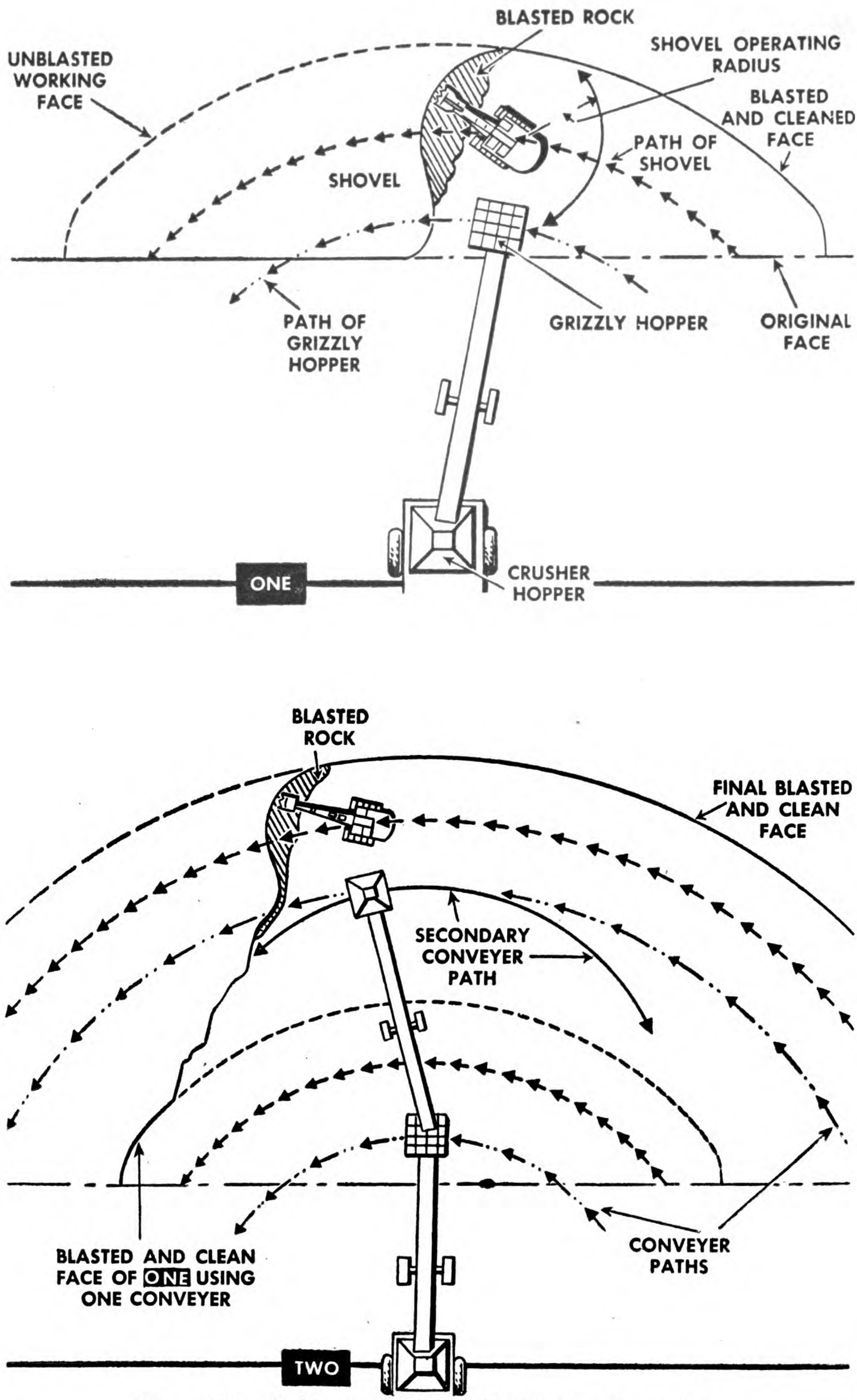


Figure 127. Working quarry face with shovel and conveyers.

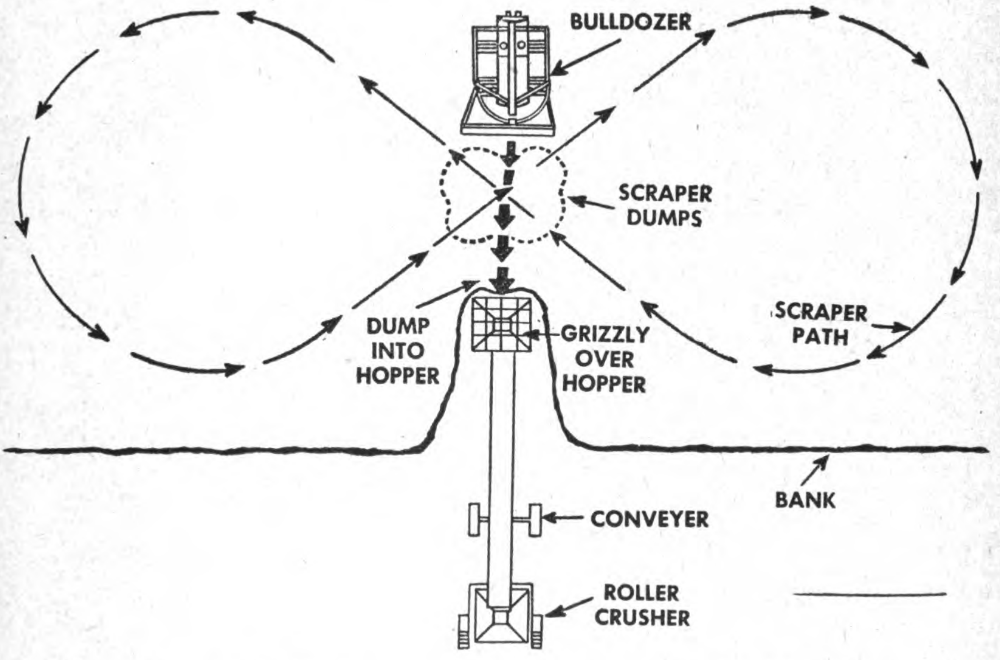
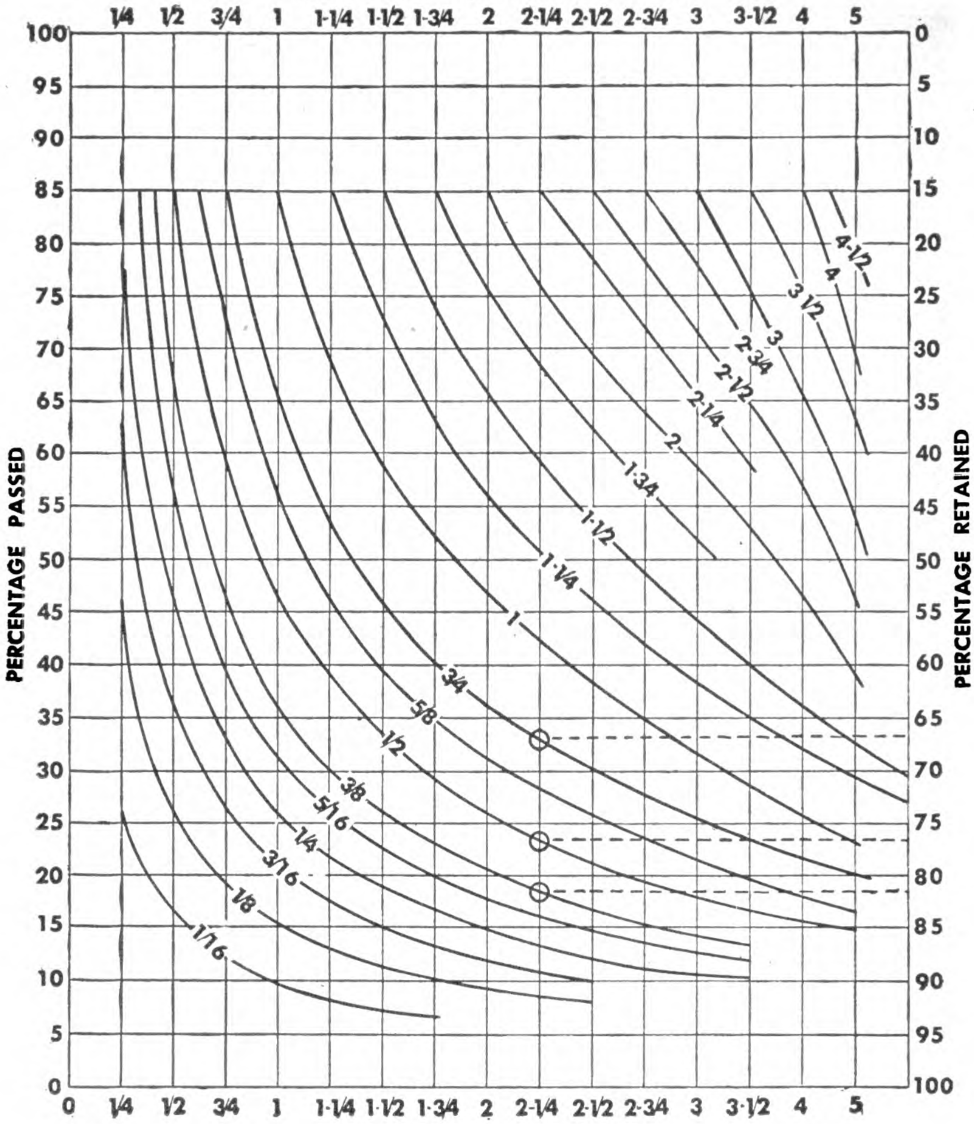


Figure 128. Working gravel pits with scrapers and bulldozers.

Table XXXIV. Gradation chart for various roller-crusher openings.

Figures within squares indicate inches



PERCENTAGE CHART

Showing approximate percentage of each size material produced by a crusher.

Problem: With the crusher set at a 2¼-inch opening, determine the per cent of rock that will come out plus ¾ inch, minus ¾ to plus ½ inch, minus ½ to plus ⅜ inch, and minus ⅜ inch.

Solution: Read from 2¼ setting at top of chart to ¾ inch, ½ inch, and ⅜ inch.

Screen size (inches)	*Per cent retained*	*Per cent passed*
¾	66	34
½	10[1]	24
⅜	5[2]	19
pan	19	
	100	

Therefore, 66% of rock is plus ¾ inch, 10% is minus ¾ to plus ½ inch, 5% is minus ½ to plus ⅜ inch, and 19% is minus ⅜ inch.

[1] Difference between 76% shown in percentage-retained column and 66% retained by ¾-inch screen.

[2] Difference between 81% shown in percentage-retained column and total of 76% retained by ¾- and ½-inch screens.

Section XI. ROLLERS

57. PHYSICAL CHARACTERISTICS. See table XXXV for data on dimensions, weight, working widths, and ground pressures of rollers.

Table XXXV. Physical characteristics of rollers

Equipment	Over-all dimensions			Weight (pounds)	Remarks
	Length (inches)	Width (inches)	Height (inches)		
Roller, road, towed, sheep's-foot, 1-drum-in-line.	152	55	59	3,920 (Empty)	Wt. loaded with water—6,270 lb. Wt. loaded with sand—8,100 lb. *Ground pressure per sq. in.* Empty —188 lb. Loaded with water—300 lb. Loaded with sand —387 lb.
Roller, road, towed, sheep's-foot, 2-drum-in-line.	175	115	58	6,040 (Empty)	Wt. loaded with water—10,240 lb. Wt. loaded with sand—13,440 lb. *Ground pressure per sq. in.* Loaded with water—254 lb. Loaded with sand—333 lb. Empty —149 lb.
Roller, road, gas-engine-driven, 3-wheel, 10-ton.	230	Rolling 76	120	20,200	Wheel base—128 in. *Road speeds* Low gear —1.4 mph Intermediate gear—2.9 mph High gear —5.0 mph
Roller, road, gas-engine-driven, tandem, 2-axle, 5- to 8-ton.	177	63	86	10,000	Wt. loaded with water—16,000 lb. Ground pressure per sq. in.—136 to 215.
Roller, road, towed, smooth-drum, 1- to 5-ton, with water tank.	162	57	59	2,010 (Empty)	Wt. loaded with water—10,000 lb. Drum diameter—48 in. Drum width —48 in.
Roller, road, towed, 13 rubber tires.	175	88	46	3,500 (Empty)	Wt. loaded—22,000 lb. Recommended gross load—14,000 lb. Rolling width—84 in. Operating speed—up to 15 mph

58. USE OF ROLLERS. a. Sheep's-foot rollers. Sheep's-foot rollers are the best machines for compacting all soils except sand, gravel, or crushed rock. They are also effective on most base-course materials containing sufficient soil binder. They should be used on layers of loose material less than 9 inches thick.

b. Three-wheel, 10-ton rollers. Three-wheel, 10-ton rollers are the best machines for compacting base courses of crushed stone containing

little or no binder. They are used to compact thin layers of soil and are also best for initial rolling of hot-laid bituminous pavements. They are not generally used for initial rolling of cold-laid pavements, although they may be used to complete compaction after sufficient initial rolling with tandem or rubber-tired rollers and curing to prevent displacement.

c. Tandem rollers. Two- or three-axle tandem rollers are the best machines for initial rolling of cold-laid bituminous pavements and for finish rolling of all types of bituminous pavements. Finish rolling with the two-axle tandem roller consists of lengthwise, diagonal, and cross rolling. Finish rolling with the three-axle tandem roller consists of lengthwise rolling only. Tandem rollers may be used to compact thin layers of soil but are not as effective as other types of rollers because of their light weight and because they compact from the top down. They should not be used to compact base courses of hard, angular material since the drums are easily dented. Tandem rollers are also used to roll cover aggregate in bituminous surface treatments.

d. Wheeled, rubber-tired rollers. The kneading action of rubber-tired rollers is highly effective in compacting cold-laid bituminous pavements. Rubber-tired rollers are also effective on base-course layers of soft crushed stone, limerock, shell, and coral where lateral movement is required to adjust and pack the particles. They are the best machine for compacting the thin layer of loose soil left on top of an embankment by the sheep's-foot roller. They are better than the three-wheel or tandem rollers for compacting thin layers of loose soil.

59. ESTIMATING WORK OUTPUT. The amount of fill material compacted per hour by a particular type roller depends on the type of soil and its moisture content, the thickness of the layer, and the speed of the roller.

a. In cubic yards. The number of cubic yards of loose material that rollers will compact per hour can be estimated by the following formula:

$$\text{Loose cubic yards} = \frac{E \times 60 \times S \times W \times D}{N \times 27}$$

Where, E = Efficiency factor.
S = Speed of travel in feet per minute.
W = Effective width of roller in feet.
D = Depth of loose layer in feet.
N = Number of passes with roller.

Note. Apply soil conversion factor (f) to obtain answer in *excavated* or *compacted* cubic yards. (See table II.)

b. In square yards. The number of square yards compacted per hour by rollers can be determined by the following formula:

$$\text{Square yards per hour} = \frac{60 \times S \times W \times E}{9}$$

Where, E = Efficiency factor.
S = Speed of travel in feet per minute.
W = Effective width of roller in feet.

60. OPERATION AND MANAGEMENT OF ROLLERS. Supervisors responsible for obtaining maximum roller efficiency should keep the following considerations in mind.

a. Depth of loose material. The depth of spread of loose material of any type which can be compacted effectively by a roller should be determined on the job by test. The following figures are a guide only:

(1) For a sheep's-foot roller, the depth of loose material should not exceed 9 inches.

(2) For three-wheel, tandem, or rubber-tired rollers, the depth of loose soil should not exceed 6 inches, the depth of bituminous material 4 inches.

b. Number of passes. The number of passes required for a given roller to compact any soil effectively should be determined on the job by test. The following figures are a guide only:

(1) At optimum soil moisture content, sheep's-foot roller compacts a 9-inch layer of loose soil to 95 per cent compaction in 10 to 12 passes. The same number of passes is required to compact a 6- to 9-inch depth of scarified subgrade. Normal operating speed is 2¼ to 3½ mph.

(2) At optimum soil moisture content, three-wheel, 10-ton roller compacts a 4-inch layer of loose soil to 75 percent compaction in three to six passes. Initial compaction (break-down rolling) of hot-laid bituminous mixes is obtained with one pass. Normal operating speed is 2 to 3 mph.

(3) At optimum soil moisture content, a tandem roller compacts a 4-inch layer of loose soil to 75 per cent compaction in two to four passes. Cold-laid bituminous mixes up to 3 inches in depth are compacted in three to five passes. Finish rolling of hot-laid bituminous mixes requires three to six passes.

(4) At optimum soil moisture content, a rubber-tired roller compacts a 4-inch layer of loose soil to 95 per cent compaction in two to four passes, and compacts a 3-inch layer of cold-laid bituminous mix in three to five passes. Normal operating speed is 10 to 15 mph.

c. Overlapping passes. Each pass should overlap the preceding one by approximately 1 foot. This eliminates uncompacted strips in the fill, road, or runway surface. (See fig. 129.)

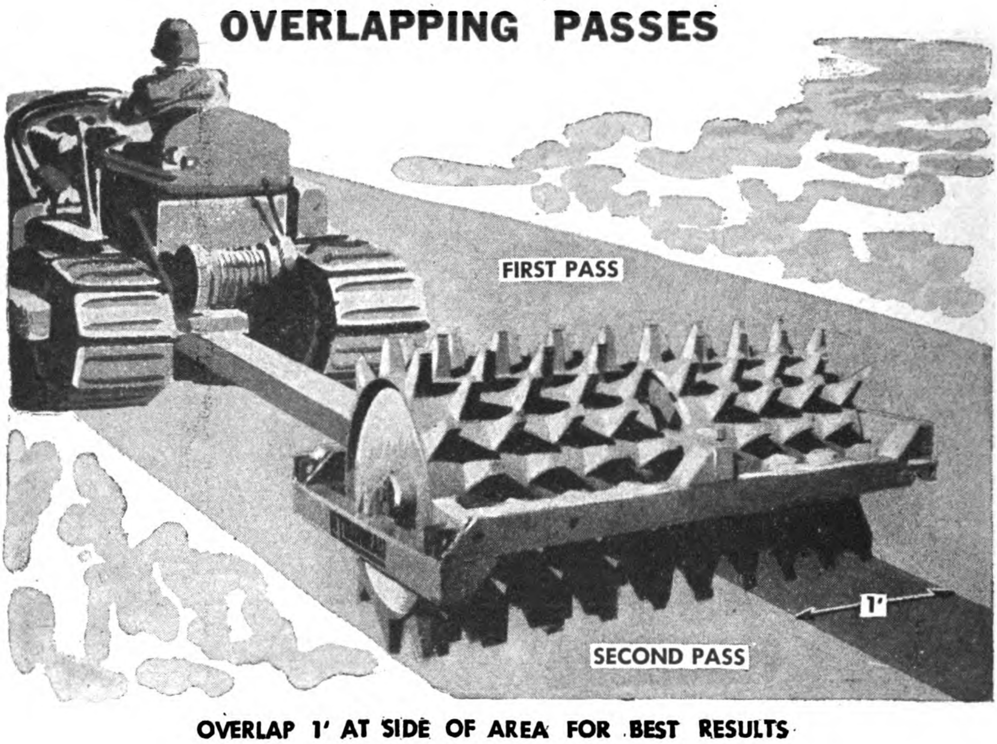


Figure 129. Overlapping passes to eliminate uncompacted strips.

d. Additional weight. Roller drums have plugs so water or other liquid can be poured in the drum to add weight. When water is used in cold climates, antifreeze must be added. (See fig. 130.) Rubber-tired rollers can be loaded with sand, gravel, or other material.

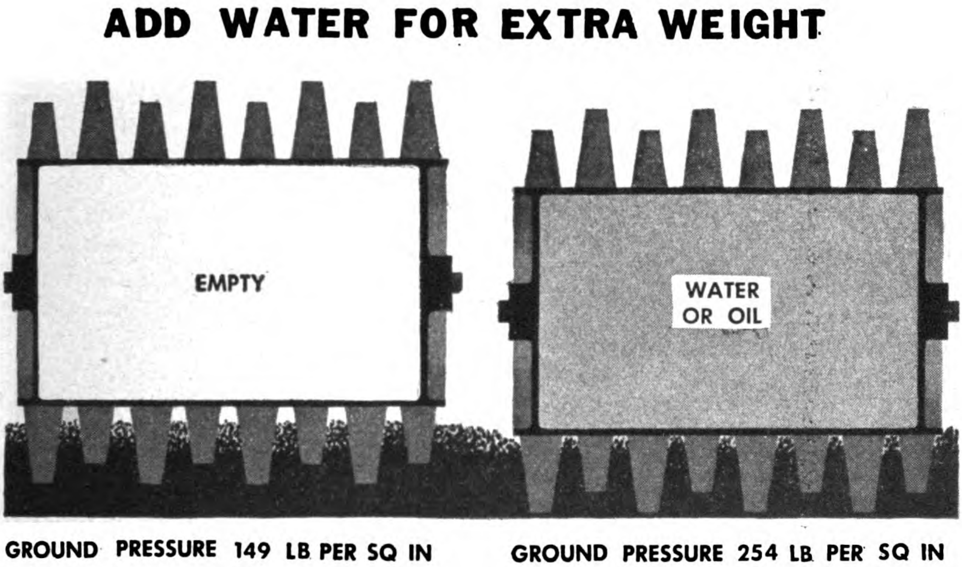


Figure 130. Sheepsfoot roller loaded with water or oil to increase ground pressure.

e. Work from ditch line to center. To control cross section when rolling base or surface courses, always begin at ditch line and work to center.

f. Operating speeds. Observe normal operating speed for each type of roller as given in paragraph 60b.

g. Turns. Rollers should not turn on the compacted surface unless absolutely necessary and should make as gradual turns as possible.

h. Surface compaction. A sheep's-foot roller leaves 1 to 2 inches of uncompacted material on the top layer of a fill. This loose material is best compacted with a rubber-tired roller.

Section XII. BITUMINOUS CONSTRUCTION EQUIPMENT

61. PHYSICAL CHARACTERISTICS. See table XXXVI for data on dimensions and weights of the various pieces of bituminous construction equipment.

62. USES. Discussed below are the uses of the various pieces of bituminous construction equipment.

a. Bituminous material distributors. These distributors transport and distribute bituminous material for paving surfaces. Distributors are equipped with a hand-spray attachment and with burners to add heat lost in transit. They should *NOT* be used to transport and distribute water.

b. Aggregate spreader. Spreaders are used to spread sand and other aggregate evenly on road and runway surfaces at controlled rates of spread.

c. Truck-mounted asphalt tank (800-gallon). These tanks transport bituminous material. They have steam coils to heat material when doing patch work. They can also be used to pump material from one source to another.

d. Trailer-mounted asphalt tank (1,500-gallon). These tanks store, heat, or transport bituminous material. It can be used to unload barrels and heat drums while draining. Combined with the trailer-type bituminous distributor it provides a unit for accurate application of bitumen to roads and runways.

e. Asphalt kettle. Kettles heat and spray asphalt or tar on road and runway surfaces. They are useful in maintaining roads and runways.

f. Asphalt heater. Heaters supply steam to tank cars, truck- and trailer-mounted asphalt tanks, asphalt storage tanks, asphalt mixers, and aggregate dryers.

g. Asphalt plant (10-unit). Asphalt plants are used for rapid construction of stabilized-base and pavement mixtures. Material can be mixed at a central location or in place on the road or runway. These plants produce bituminous mixtures and stabilized mixtures of natural material or soil cement at a rate of approximately 100 tons per hour. See table XXXVI for units included in the 10-unit plant.

63. APPLICATION AND MANAGEMENT. a. Central-plant operations. Units of the 10-unit asphalt plant can be assembled into a central plant to produce any type of either hot- or cold-laid bituminous mixtures. The number and type of units used depends on the type mixture to be produced. See table XXXVII for typical output of central plant. Following is a description of combinations most commonly used.

(1) *Hot-mix central plant.* The hot-mix central plant is used to produce mixes that are laid and compacted at temperatures between 225° and 350° F, using bitumen whose applied temperature range is 225° to 350° F. Asphalt cement is normally used. Design of hot-laid mixes is discussed in TM 5–255. See table XXXVIII and figure 131 for equipment used and plant lay-out. Plants of this type handling a large volume of work under subarctic conditions produced an average of 93 tph each and used 3.5 gallons of fuel oil to dry each ton of aggregate.

Caution: Cutback asphalts contain inflammable solvents. Because of the fire and explosion hazard, medium and rapid curing cutbacks are not used in hot mixes where aggregate temperature is above the safe application temperature of the cutback.

(2) *Cold-mix central plant.* The cold-mix central plant is used to produce mixes that are laid and compacted at temperatures less than 150° F. Bituminous materials commonly used are the heavier grades of tar and cutback asphalts or asphalt emulsions. Design of cold-laid mixes is discussed in TM 5–255.

(*a*) *Cutback asphalt mixes.* The plant used to produce this type of mix is assembled with an open conveyer belt between the dryers and mixing unit. Aggregate is heated in the dryers to remove moisture. As aggregate is carried from the dryers to the mixing unit on the open

Table XXXVI. Physical characteristics of bituminous equipment

Equipment	Over-all dimensions Length (inches)	Width (inches)	Height (inches)	Weight (pounds)	Remarks
Distributor, bituminous-material, trailer-mtd, 1,250-gallon.	244	93	105	Empty 10,700 Loaded 21,000	Distributor-pump-capacity 375 gph
Spreader, aggregate, towed-type, traction-powered, 8-ft width.	108	49	37	Empty 1,655	Max aggregate size—1 in Hopper capacity (struck)—1.12 cu yd Spreading width—8 ft (max)
Tank, asphalt, steel, truck-mounted, with heating flues, 800-gal.	266	94	108	Empty 19,500 Loaded 22,750	Pump capacity—90 gpm Road speed—40 mph
Tank, asphalt, steel, trailer-mounted, with steam coils, 1,500-gal.	240	96	114	Empty 10,000 Loaded 22,750	Dbhp required—20 (min) Rated heating capacity—3 to 4° F rise in asphalt temp per min
Kettle, asphalt, trailer-mounted, 110-gal, w/ motor-driven hand spray.	117	53	46	Empty 1,262 Loaded 2,357	Pump capacity—10 gpm Towing speed—20 mph (max)
Kettle, asphalt repair, trailer-mounted, w/ motor-driven hand spray, 165-gal-capacity.	126	64	72	Empty 1,575 Loaded 3,000	Pump capacity—10 gpm Towing speed—20 mph (max)
Heater, asphalt, trailer-mounted, two-car, 28-hp boiler.	163	62	69	Empty 4,100 Loaded 5,500	Towing speed—50 mph (max)
Asphalt plant, 110-200 tons per hr, 10-unit *Unit I*—Conveyer, transfer, gas-engine-driven.	762	103	310	Empty 8,200	Towing speed—15 mph (max) Capacity—up to 300 tons per hr Belt width—24 in
Unit II—Dryer, aggregate, dual-drum.	432	126	178	Empty 38,500 Loaded 43,500	Capacity—80 to 150 tons per hr Towing speed—10 mph (max)
Unit III—Elevator, bucket, inclosed.	306	40	54	Empty 5,220	Capacity—60 to 120 tons per hr

Table XXXVI. Physical characteristics of bituminous equipment—Continued

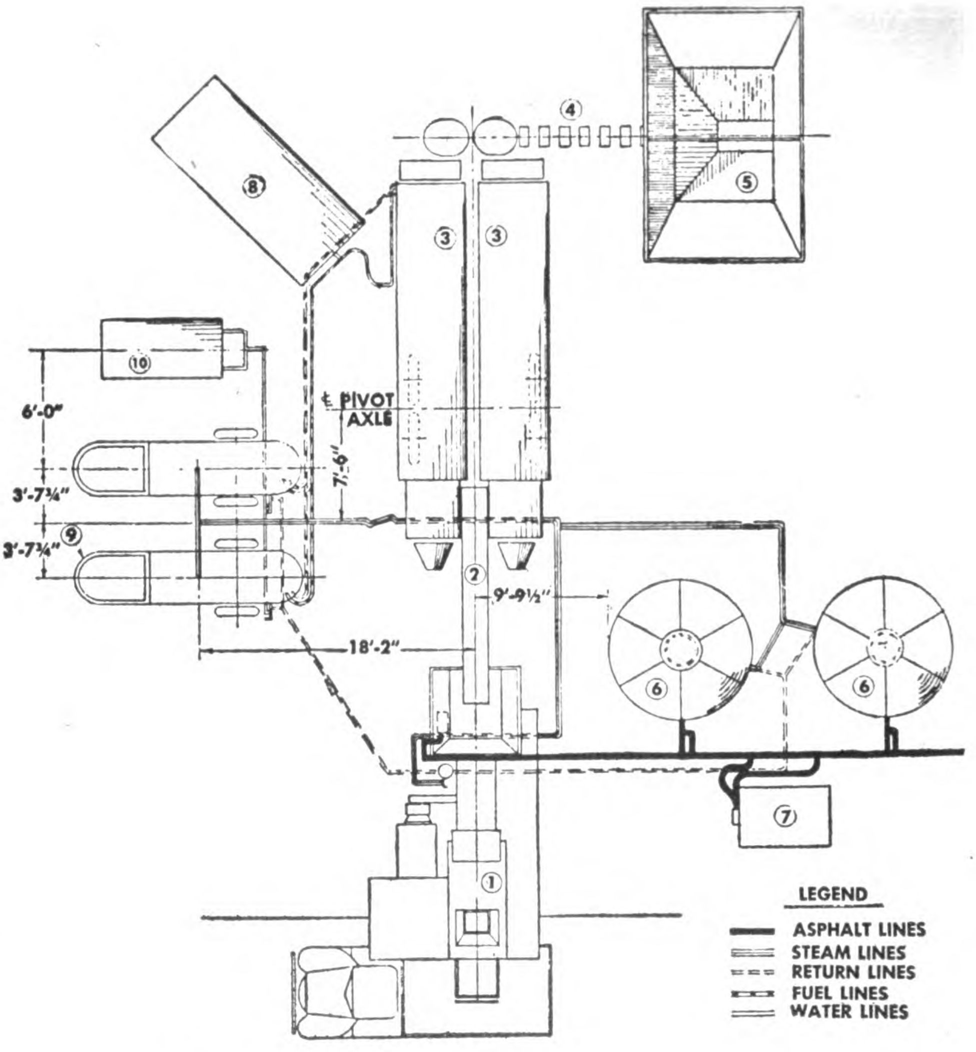
Equipment	Over-all dimensions			Weight (pounds)	Remarks
	Length (inches)	Width (inches)	Height (inches)		
Unit IV—Finisher, asphalt, 12-ft.	182	Min 124 Max 150	84	Empty 23,100 Loaded 33,000	*Operating speeds (fpm)* Low range—7.9, 11.4, 13.7, 20.0 Low-range reverse—11.3, 16.4 High range—17.5, 25.3, 30.6, 44.5 High-range reverse—25.0, 35.1 *Transit speeds (fpm)* Forward—56, 81, 98, 142 Reverse—80, 116
Unit V—Heater, asphalt three-car, two units per plant.	164	67	80	Empty 5,000 Loaded 7,100	Towing speed—50 mph (max) Capacity—three 10,000-gal railroad tank cars simultaneously
Unit VI—Loader, bucket two units per plant.	*Dryer loader* 235 *Mixer loader* 214	 116 116	 233 208	 Empty 20,975 Loaded 21,635 Empty 19,855 Loaded 20,405	*Crowding speeds (fpm)* 2.6 8.93 3.18 10.53 *Travel speed (fpm)* 3.88 12.87 Forward—58.0, 183.0, 251.0 4.75 15.75 Reverse—47 5.6 19.24 7.31
Unit VII—Mixer, asphalt.	236	117	140	Empty 27,500 Loaded 42,500	Towing speed—10 mph (max) Capacity—110 to 200 tons per hr
Unit VIII—Piping for boilers, dryer, mixer, tanks, etc.	Cubage packed 225 cu ft			5,600	
Unit IX—Pump, asphalt, w/distributor attachments.	108	85	84	4,100	Hand-spray attachment—25 ft long Capacity—350 gpm
Unit X—Tank, asphalt storage, steel, bolted, 4,000-gal, two units per plant.	Outside diameter 111		109	Empty 3,100	*Loaded weight (pounds)* Gasoline—27,000 Asphalt—36,700 Water—36,900

Table XXXVII. Typical output of central plant

Finished paving (Square yards per hour)			
Thickness (inches)	Minimum	Average	Maximum
1	910	1,820	2,725
2	455	910	1,365
3	305	605	910
4	225	455	680
5	180	365	545

Table XXXVIII. Equipment used in hot-mix central plant

Equipment	Number of units	Purpose
Unit II—Aggregate dryer	1	To remove moisture from aggregate and heat it to desired temperature.
Unit III—Bucket elevator	1	To elevate heated and dried aggregate from dryer to mixer.
Unit V—Asphalt heater	2	To supply steam to dryer, mixing unit, asphalt storage tanks, and steam-jacketed asphalt piping.
Unit VI—Bucket loader (dryer loader)	1	To feed dryer with aggregate.
Unit VII—Asphalt mixer	1	To mix bitumen and aggregate correctly and to combine them in a thorough bituminous mixture.
Unit VIII—Piping	1 set	To fulfill steam, asphalt, fuel, and water requirements.
Unit IX—Asphalt pump	1	To perform all bitumen pumping functions not performed by pumps on mixer unit.
Unit X—Asphalt storage tank	2	To store enough asphalt for sustained mixer operation.
Auxiliary Equipment		
Unit IV—Asphalt finisher	1	To spread bituminous mix at controlled rates of spread. This unit can be replaced by hand tools or graders.
Hopper and reciprocating feeder	1	To supply aggregate to bucket-loader feeding dryer.
750-gallon, two-compartment, skid-mounted tank	1	To supply fuel and water to asphalt heater.



Key:

1. Asphalt mixer (unit VII).
2. Bucket elevator (unit III).
3. Aggregate dryer (unit II).
4. Bucket loader (unit VI).
5. Hopper.
6. Asphalt storage tanks (unit X).
7. Asphalt pump (unit IX).
8. 1,500-gallon, trailer-mounted asphalt tank.
9. 3-car heaters (unit V).
10. 750-gallon, two-compartment, skid-mounted tank.

Figure 131. Layout of hot-mix central plant.

conveyer it is exposed to the air and cooled to a safe mixing temperature. This temperature depends on the bituminous material used. (See table VII, TM 5–255.) See figure 132 for equipment used and plant lay-out.

(*b*) *Asphalt emulsion mixes.* The plant used to produce asphalt emulsion mixes does not require dryers. Asphalt emulsion contains water, and it is therefore unnecessary to remove moisture from the aggregate.

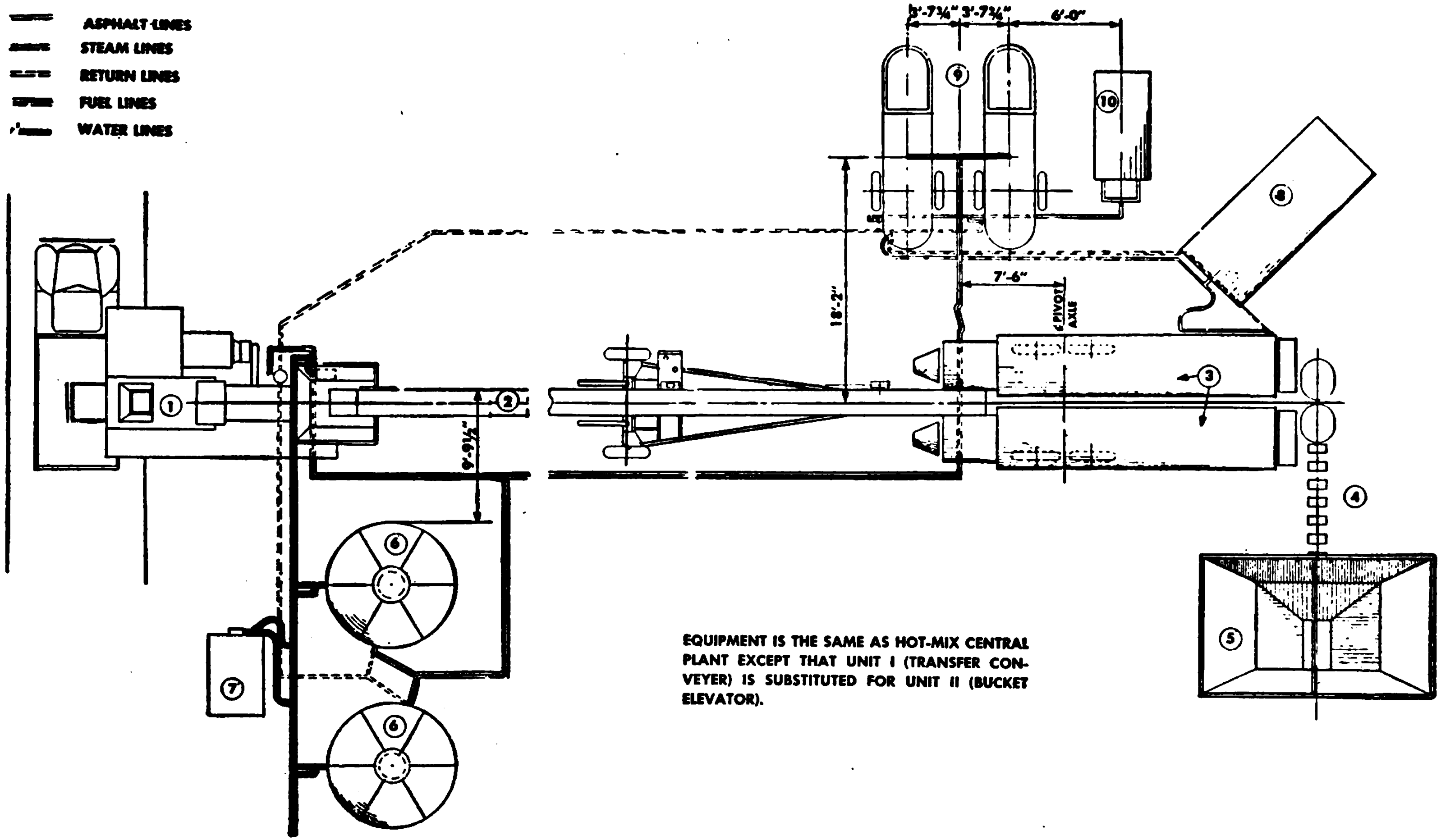


Figure 132. Equipment used and lay-out of cold-mix central plant.

(3) *Hauling and spreading.* (*a*) *Hot-laid mixes.* Hot mixes are normally hauled to the paving site and dumped into finishers which spread and partially compact the material to the proper thickness. Mixes can also be dumped and spread by hand tools. Compaction of hot-laid mixes must be completed before the material cools.

(*b*) *Cold-laid mixes.* Cold mixes are normally spread by finishers. They can also be dumped into windrows and spread by graders, as described for mixed-in-place construction, or spread by hand. Compaction of cold-laid mixtures is a more gradual process which depends on the rate of curing and hardening of mixture after spreading. Normally, intermittent rolling over several days is required.

b. Travel-plant operations. Use of travel plants permits mixing directly on the site where material is to be laid. They produce only cold-laid mixes. See table XXXIX and figure 133 for equipment used and plant layout. See table XL for typical output of travel plants.

Table XXXIX. Equipment used in travel plant

Equipment	Number of units	Purpose
Unit VI—Bucket loader (mixer loader)	1	To pick up aggregate from windrow and deliver it to mixer hopper.
Unit VII—Asphalt mixer	1	To mix bitumen and aggregate correctly and to combine them in a thorough bituminous mixture.
Unit X—Asphalt storage tank	1–2	To store enough asphalt for sustained mixer operation.
Auxiliary Equipment		
Trailer-mounted asphalt tank	1	To supply material to bitumen tank of mixer.
Truck-mounted asphalt	1	To supply material from central storage tanks to trailer-mounted asphalt tank.
Unit II—Aggregate dryer[1]	1	To remove moisture from aggregate.
Unit V—Asphalt heater[1]	1	To supply heat to dryer.
Unit VI—Bucket loader[1] (dryer loader)	1	To pick up aggregate from windrow and deliver it to dryer.
750-gallon, two compartment, skid-mounted tank[1].	1	To supply fuel and water to asphalt heater.

[1] Required only when field conditions do not permit drying aggregate by wind and sun.

(1) *Mixing and spreading.* Aggregate is placed on the road or runway, mixed, and shaped by graders into windrows of uniform size. The windrows are built to contain a given volume of aggregate; maximum volume is 10 to 14 cubic feet per linear foot of windrow. Material is picked up, mixed with bitumen, and deposited in windrows by the

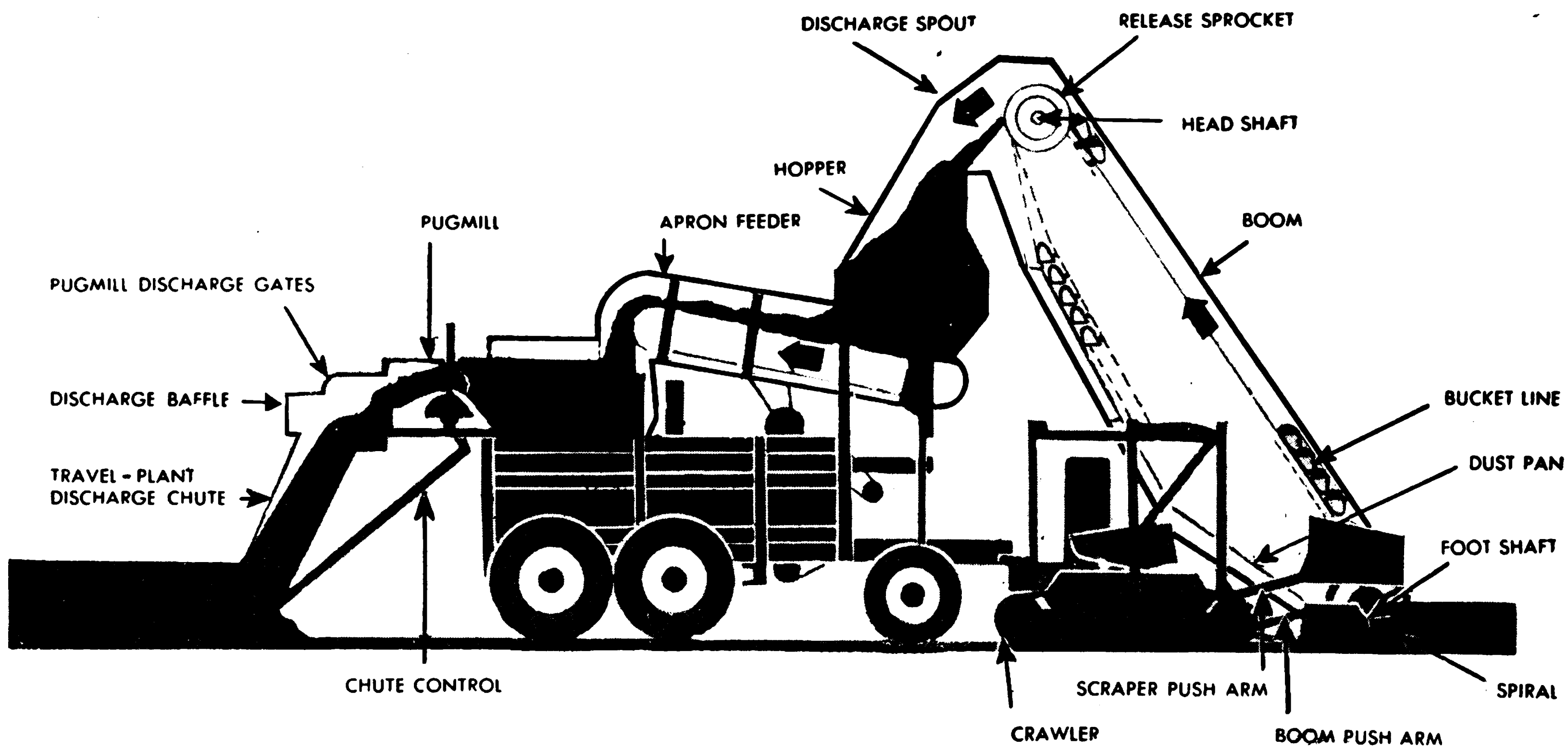


Figure 133. Layout of travel plant.

Table XL. Typical output of travel plant

Thickness (inches)	Finished paving (Square yards per hour)		
	Minimum	Average	Maximum
1	1,600	2,200	4,000
2	800	1,100	2,000
3	535	735	1,330
4	400	550	1,000
5	320	450	800

travel plant. The mixture is spread by graders and compacted by rollers or is discharged into a finisher (unit IV of asphalt plant) and spread.

(2) *Use of finisher with travel plant.* Using the asphalt finisher behind the mixer to spread and compact is feasible but is not recommended because it restricts the output of the mixer.

When using the finisher:

(*a*) The windrow must be uniform to feed and synchronize it properly.

(*b*) The capacity of the travel plant is reduced, because the finisher with its maximum width of 10 to 12 feet requires that material be deposited in two windrows.

(*c*) Aggregate windrows must be close together because of the narrow strips required. This makes grader drying of the windrowed aggregate difficult, and also limits the area available for asphalt supply trucks and other equipment.

(3) *Comparison of central- and travel-plant applications.* The mixing method chosen depends largely on the mix. The mix depends on the available supply of asphalt and aggregate and on weather conditions. Following is a list of advantages and disadvantages of central and travel plants:

Central plant	*Travel plant*
1. Can produce all types of hot and cold mixes.	1. Produces cold mixes only.
2. Operations not affected as much by adverse weather (capable of 24-hour operation at all times).	2. Higher capacity than central plant.
3. Equipment centrally located and supply maintenance simplified.	3. Permits using aggregates at the site with a minimum of rehandling.
4. Adapted to work with mechanical finisher.	4. Requires less equipment.
5. Keeps heavy, bulky equipment off road or runway subgrade.	5. Lays mixed material directly on road or runway surface without trucking.

c. Mixing in place. Bitumen and aggregate can be mixed *in place* on a road or runway surface by either of the following combinations of equipment.

(1) *Rotary tiller, motorized grader, and bituminous distributor.* Bitumen is spread on the aggregate by the distributor and mixed at a rate of approximately 100 to 200 cubic yards per hour by the tractor-drawn rotary tiller. Mixed material is spread and leveled by motor graders at a rate of approximately 150 square yards per hour per grader. See table XLI for output of bituminous distributor.

(2) *Motorized grader and bituminous distributor.* Bitumen is spread on the aggregate by the distributor and mixed at a rate of approximately 150 to 300 cubic yards per hour per grader. Mixed material is spread and leveled by motor graders at a rate of approximately 150 square yards per hour per grader.

Table XLI. Typical output of 1,250-gallon trailer-mounted distributor

Spraybar length (ft.)	4	6	8	10	12	16	20	24	Square yards covered per load
Rate of application (gal. per sq. yd.)	Square yards per minute								
0.1	400	600	800	1,000	1,200	1,600	2,000	2,400	12,500
0.2	200	300	400	500	600	800	1,000	1,200	6,250
0.3	133	200	267	333	400	533	667	800	4,167
0.4	100	150	200	250	300	400	500	600	3,125
0.5	80	120	160	200	240	320	400	480	2,500
0.8	50	75	100	125	150	200	250	300	1,563
1.0	40	60	80	100	120	160	200	240	1,250
2.0	20	30	40	50	60	80	100	120	625
3.0	13	20	26	33	40	53	67	80	416

Section XIII. CONCRETE EQUIPMENT

64. GENERAL. Concrete equipment consists of concrete mixers, pavers, spreaders, finishers, steel forms, and auxiliary equipment such as hoppers, vibrators, and wheelbarrows.

65. CONCRETE MIXERS AND PAVERS. a. Physical characteristics. See table XLII for data on dimensions, weights, operating data, and fuel and oil consumption of concrete mixers and pavers.

b. Use of concrete mixers and pavers. Concrete mixers and pavers are used to mix concrete. In addition, pavers distribute concrete to pave roads or runways. Concrete mixers are trailer-mounted

Table XLII. Dimensions, weights, operating data, and fuel and oil consumption of concrete mixers and pavers

Item	Concrete mixer	Paver
Model	14S	34E
Drum capacity (cu. ft.)	14[1]	34[2]
Hourly capacity (cu. yd. per hr.)	10–15	35–40
Rating (sack)	2	5
Power unit		
Horsepower	28.5	96
Fuel consumption	0.5 gph	5.6 gph
Water tank		
Supply (gal.)	Not equipped	100
Measuring (gal.)	30	60
Drum dimensions		
Diameter (in.)	57	79
Width (in.)	41½	67
Boom (Paver only)		
Length (ft.)	----	35.0
Spread radius (ft.)	----	32.5
Swing arc	----	160°
Over-all dimensions		
Length	10′ 1″	61′ 5″
Width	7′ 4″	11′ 3″
Height	10′ 0″	16′ 0″
Shipping data		
Export boxes	1	4
Cubage	627 cu. ft.	3,215 cu. ft.
Weight	10,400 lb.	58,700 lb.

[1] 15.4 cubic feet when operated on level to 10 percent slope.
[2] 37.4 cubic feet when operated on level to 10 percent slope.

and are used as fixed plants. Pavers are crawler-mounted and move with the job.

c. Work output of concrete mixers and pavers. Table XLII lists the output of the engineer mixer and paver.

d. Central-plant batching equipment. A central batching plant (fig. 36) is used to store and proportion fine and coarse aggregate before delivery to the paver. The bulk cement plant is used to unload cement from trucks or boxcars and to store and proportion it for delivery to batching trucks. Dump trucks can be converted into batching trucks by installing expedient batch partitions in the dump body. Physical characteristics of batching and bulk cement plants are given in table XLII.

e. Supervision for maximum work output. Supervisors responsible for obtaining maximum mixer and paver efficiency should keep the following considerations in mind.

(1) Keep sand, gravel, and cement stock piles as close to mixer charging hopper as possible. (See fig. 134.)

(2) Operate mixer or paver as level as possible. If necessary, dig in wheels of fixed plant until mixer is level.

Table XLII (Continued). Dimensions, weights, and operating data of batching and bulk cement plants.

Item	Batching plant	Bulk cement plant[3]
Model	B6-1 (Scale) BCP-300 (Bin)	63-8 (Batcher) P 3105 (Bin)
Gates		
Bin	12″ x 18″	9″ x 11″
Discharge	10½″ x 3′-7″	9″ x 11″
Scale capacity (lb.)	7,000 (3-beam)	1,000 (1-beam)
Weight		
Empty (lb.)	17,300	20,400
Loaded (lb.)	227,300	133,200
Over-all dimensions		
Length	19′-9″	13′-3″
Width	12′-11¾″	10′-0″
Height	29′-0″	38′-10″
Truck clearance		
Height	11′-9″	10′-10″
Width	9′-0″	8′-6″
Shipping data		
Number of pieces	6	3
Cubage (cu. ft.)	2,650	1,290
Weight (lb.)	17,700	23,276
Number on a gondola car	2	4

[3] Cement-conveying system.
30 ton per hour (tph) bucket elevator.
5-cubic-yard truck-unloading hopper.
18-hp., 4-cylinder engine.

(3) When operating with a fixed plant, dig in loading hopper of mixer to facilitate charging. (See fig. 135.)

(4) Use ramps (fig. 136) to make dumping easier when charging with wheelbarrows. Also use ramps when pouring large slabs to facilitate wheelbarrow handling and to distribute wheelbarrow loads around the job.

(5) When possible, use wheelbarrows to charge mixer hopper; use trucks to charge paver skip. Load gravel or stone first, cement second, and cover whole batch with sand. Gravel scours hopper bottom and carries rest of load into mixer or paver. Sand cover prevents excessive loss of cement dust as batch enters mixing drum. This sequence generally allows cement man just enough time to open bags and deposit cement over gravel or stone before sand is dumped.

(6) Concrete mixes are designed according to the principles set forth in section I, chapter 8, FM 5-10. Amount of water added to each batch varies with moisture content of aggregate. The mix is adjusted for changes in water content of aggregate resulting from condensation at night, drying out during the day, new aggregate, or rainfall.

(7) For thorough mixing, carry material to a point about two-thirds up drum. This can be regulated by increasing speed of drum for wet mix or decreasing it for dry mix.

(8) Keep entire machine clean. At beginning of each day coat machine with "form oil" to help prevent concrete and cement sticking to

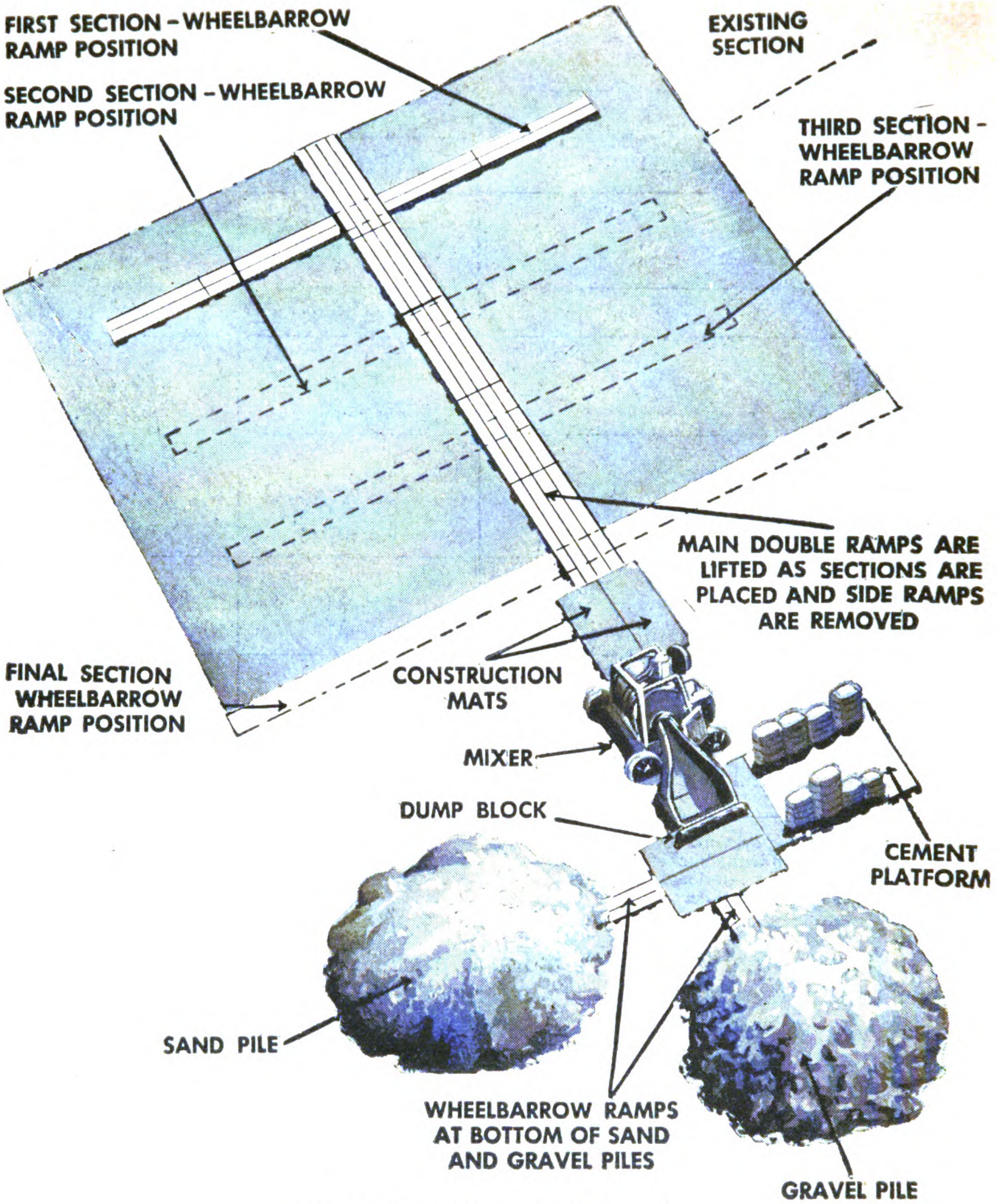


Figure 134. Mixer plant lay-out.

bare steel or paint. Each time machine shuts down, run a half batch of gravel or rock and water through drum for 4 or 5 minutes to loosen up any concrete sticking to it. Wash, clean, and re-oil entire machine each evening or when it is shut down for a period of time. Do not pound skip bottom and drum. This leaves dents and bumps around which concrete and cement will build up.

(9) In cold and freezing weather, heat aggregates and water to prevent freeze-up. Drain water tank and water line each time mixer is shut down.

(10) When operating a mixer as a central plant, move it each time a justifiable decrease in haul distance can be obtained.

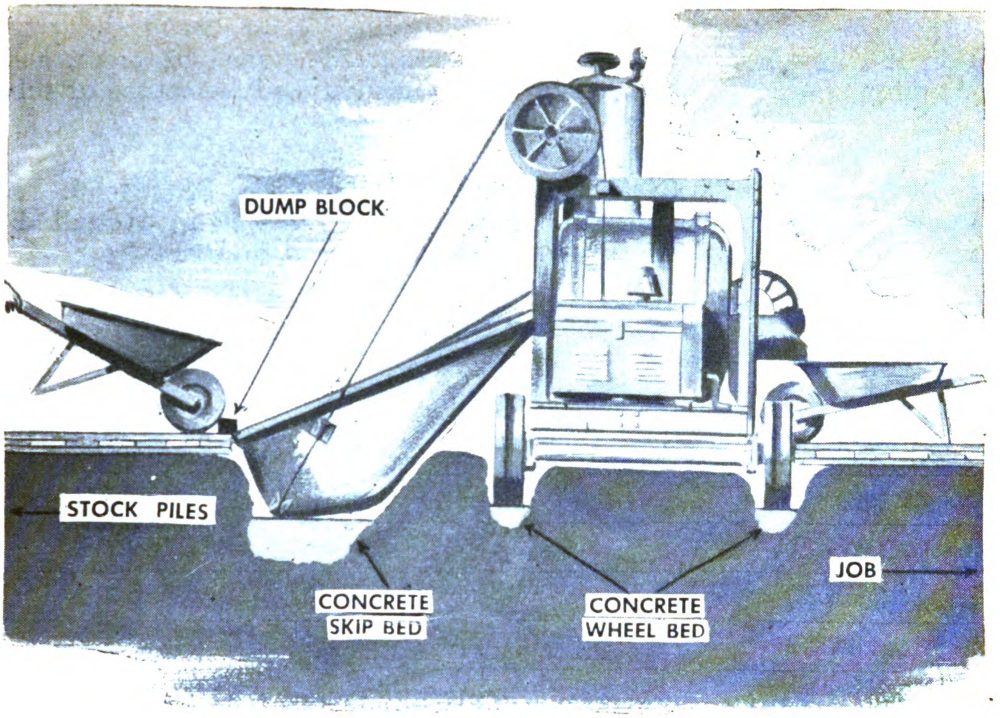


Figure 135. Dug-in charging hopper to facilitate charging.

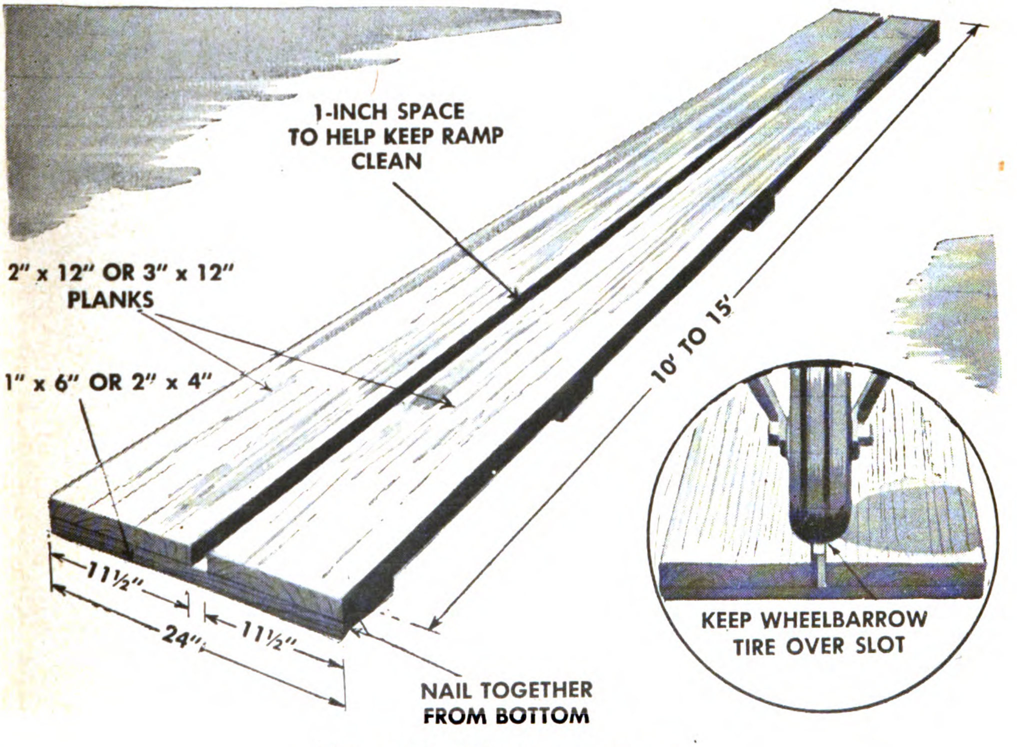


Figure 136. Wheelbarrow ramp.

(11) Wherever possible, use paver outside the forms. In this position it will not interfere with laying reinforcing steel or mesh, and charging trucks and paver crawlers will not rip up base course or subgrade.

66. FORM-RIDING CONCRETE SPREADER AND FINISHER. a. Physical characteristics. Table XLIII lists the weight, over-all dimensions, and operating capacity of spreaders and finishers.

Table XLIII. Weight, over-all dimensions, and operating capacity of the form-riding concrete spreader and finisher

	Spreader	Finisher
Tread (inside forms)	20′–0″	20′–0″
Length (over-all)	11′–5″	11′–1″
Width (over-all)	23′–10″	21′–6″
Height (over-all)	5′–11″	5′–5″
Total weight	15,500 lb.	12,000 lb.
Vibrator speed	None	4,100 rpm.
Traction speeds (fpm.)		
Low	7.75	7.4
2d	11.8	9.9
3d	14.1	12.5
4th	86.8	16.5
5th	----	76.7
6th	----	101.6
Spreader trolley (strokes per min.)	187	----
Screed speed (strokes per min.)		
1st	None	48
2d	None	60
3d	None	64
4th	None	79

Table XLIII. (Continued)
Hourly finisher production

Traction speed		Square yards per hour (20-foot road width)
Gear	Feet per minute	
1st	7.4	980
2d	9.9	1,320
3d	12.5	1,670
4th	16.5	2,200
5th	76.7	10,250
6th	101.6	13,550

Table XLIII. (Continued)
Hourly spreader production

Traction speed		Square yards per hour (20-foot road width)
Gear	Feet per minute	
Low	7.75	1,030
2d	11.8	1,575
3d	14.1	1,880
4th	86.6	11,550

b. Use of spreader and finisher. (1) The spreader follows the paver and spreads the intermittent batch output of the paver in a continuous, uniform slab of concrete between road forms. It rides the forms to maintain the height of surface concrete. The spreader gives a uniformly level surface for the finisher.

(2) The finisher follows the spreader and rides the forms in the same way. It has a front screed, a vibrator, and a rear screed. The front screed acts as a strike-off bar and brings the surface *nearer* its final level. The vibrator moves up and down with a simultaneous rocking motion and consolidates the concrete. The rear screed strikes off the finished surface. Any surface irregularities are smoothed out with hand screeds during other hand operations such as edging and trimming joints.

c. Supervision for maximum work output. Supervisors responsible for obtaining maximum spreader and finisher efficiency should keep the following considerations in mind.

(1) *Spreaders.* (*a*) Keep top side of form clean, dry, and free of form oil. This increases traction.

(*b*) Help spread concrete in front of spreader by running bucket forward as concrete is dumped.

(*c*) Slow spreader down to take smaller bites of concrete, if too much concrete is placed in front of spreader.

(*d*) Keep two men ahead of spreader to clean off forms where excess concrete has spilled over and to fill in low spots ahead of spreader.

(*e*) Adjust spreader so it does not leave too much concrete, overloading finisher screeds; and does not trim too deep, starving finisher.

(*f*) Load the frame with ballast such as sandbags or bags of cement when operating up grades of 6 to 10 percent.

(*g*) Set bottom of trolley blade high enough to keep concrete in contact all along the strike off. Distance above strike off varies with maximum size of aggregate and stiffness of mix.

(*h*) On superelevated curves, especially on steep grades, the tendency of the mass of concrete is to work toward the low side. Adjust strike-off plate to compensate for this tendency by lowering strike off on low side and raising it on high side.

(2) *Finishers.* (*a*) Check and set crown adjustments on screeds at the beginning of each day and each time the finished profile changes. Screeds must be adjusted gradually until final screed setting is made.

(*b*) Clean screed faces each day and on the after-hour's check. Best results are obtained by cleaning the bottom of the screeds every 100 feet.

(*c*) Tilt screeds forward slightly on dry mixes or when coarse aggregates are used.

(*d*) Correct setting of front screed, vibrator, and rear screed is shown in figure 137. *Surge* varies with type of mix. *Mass* varies with amount of material left by spreader. Mass height should be from 4 to 8 inches along front screed.

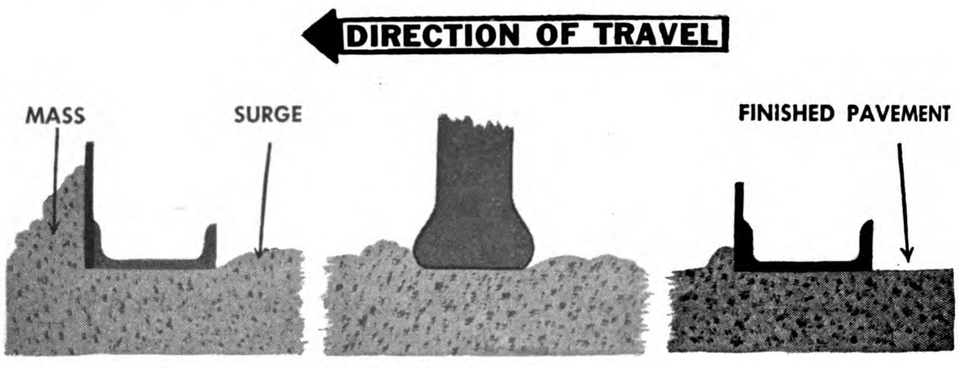


Figure 137. Side view of finisher, showing concrete and grout ahead of front and rear screeds.

67. STEEL CONCRETE FORM. a. Physical characteristics. See table XLIV for data on dimensions and weight of steel concrete forms.

b. Use of steel forms. Steel forms are used to provide straight sides on concrete pavement, to control concrete thickness, and to provide a

Table XLIV. Dimensions and weights of steel concrete forms

Form dimensions	
Working	
Length	10′-0″
Height	8″
Over-all	
Length	10′-6″
Height	8″
Width	8″
Stake dimensions	
Diameter	1″
Length	18″ and 24″
Stakes per form	3
Working weight of one form (including 3 stakes)	184 lb
Shipping data (2 forms nested with stakes)	
Cubage	7 cu ft
Shipping weight	368 lb

smooth, stable track on which finishing and spreading machines can operate.

c. Man-hours required to set forms. An eight-man crew can strip, clean, oil, and reset 200 linear feet of steel forms an hour. After completely oiling the steel form, the top side or traction edge of the form must be wiped free of oil.

Section XIV. DITCHING MACHINES, MOWERS, SWEEPERS, LOADER BUCKETS, CLEARING UNITS, EARTH AUGERS, TRACTOR-MOUNTED WINCHES, AND CHAIN SAWS

68. PHYSICAL CHARACTERISTICS. See table XLV for data on dimensions and weights of ditching machines, mowers, sweepers, loader buckets, clearing units, earth augers, and tractor-mounted winches.

69. USE OF EQUIPMENT. a. Ditching machines. (1) *Use.* Ladder-type ditching machines are used for general-purpose ditching and trenching. They are crawler-mounted and travel forward as they dig. Material is deposited in a spoil bank beside the ditch. Ditching machines are capable of digging tough or sticky clay, shale, coral rock, and frozen soil. They will also cut through thin pavements.

(2) *Estimating work output.* The length of ditch that can be cut in a given time depends on type of material and depth of cut. Speed varies from 1 to 8 feet per minute. To estimate capacity accurately, tests should be made in the type soil to be dug.

b. Mowers. (1) *Use.* Mowers are used to cut high grass, weeds, and light shrubbery. They cut 2 to 9 inches above ground level.

(2) *Estimating work output.* The area mowed in a given time can be estimated from tractor speed and effective cutter-bar width. (See table IV.) Under normal conditions mowers cut 1½ to 3 acres an hour.

c. Rotary-broom sweeper. (1) *Use.* Rotary-broom sweepers are used to clean road and runway surfaces before asphalt is laid. They can also be used to sweep away sand, dust, gravel, and light snow.

(2) *Estimating work output.* Work output can be estimated from tractor speed and effective broom width. (See table IV.) Under normal conditions, sweepers can clean approximately 2,500 square yards an hour.

(3) *Application and management.* See figure 138 for proper method of routing for efficient operation.

d. Loader bucket. (1) *Use.* Loader buckets are used to load trucks and trailers with earth and aggregate. They can also be used for excavating, backfilling, light grading, leveling, loading and unloading cargo, and stock-pile loading.

(2) *Work output.* Table XLVI gives typical output of ¾-cubic yard loader bucket for various operations.

e. Tractor-mounted clearing unit. (1) *Use.* Tractor-mounted clearing units are used to pull and haul trees and stumps. They can

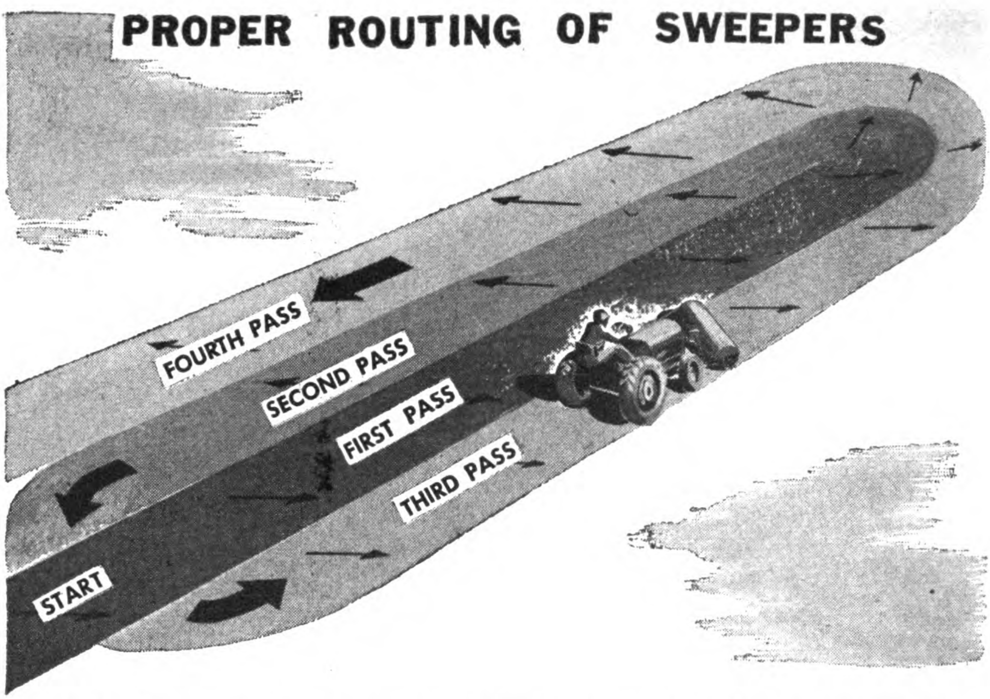


Figure 138. Proper routing of sweepers. When a strong wind is blowing, work with it.

also be used as a hoist and to extricate mired equipment. With adequate rigging, there is no limit to the size tree or stump they can remove.

(2) *Application and management.* (*a*) *Tree and stump removal.* Figure 139 shows proper methods of rigging for light, medium, and heavy pulling.

(*b*) *Hoisting.* See figure 140 for use of clearing unit as a hoist to load and unload cargo and equipment.

(*c*) *Extricating mired equipment.* See figure 141 for use of clearing unit to extricate equipment mired in mud or swampy ground.

(*d*) *Operation in rough or swampy terrain.* Where it is difficult or impossible to operate tractors, clearing units can pull themselves to the clearing site. See figure 142 for method of travel in steep or swampy terrain.

(*e*) *Combined pulling and skidding.* See figure 143 for method of removing and skidding trees or stumps to waste area in one operation.

f. Earth augers. (1) *Use.* Earth augers are used to dig post holes or holes for placing explosive charges. They can also be used to investigate type and condition of soils below ground surface.

(2) *Work output.* Augers can dig at a rate of approximately 1 to 5 feet per minute depending on type and condition of soil. An average value in common earth is $2\frac{1}{2}$ feet per minute.

g. Tractor-mounted winches. Tractor-mounted winches are used to extricate mired equipment and to skid and haul trees and stumps. They can also be used to remove small trees in clearing operations. See table XLVII for single-line pull of various sizes of winch.

h. Gasoline-powered chain saw. (1) *Use.* Gasoline-powered chain

Table XLV. Physical characteristics of equipment

Equipment	Over-all Dimensions			Weight (pounds)	Remarks
	Length (inches)	Width (inches)	Height (inches)		
Ditching machine, ladder-type, crawler-mounted, gas-engine-driven.	294 213	*Working* 132 *Transport* 92	192 126	23,000	Width of cut—18 or 24 in. Depth of cut—0 to 99 in. *Operating speed (mph).* 1st gear—0.6 2d gear—0.75 3d gear—2.19 Reverse—0.60
Mower, tractor-driven, 7-ft cutter bar, pneumatic-tired.	180	149	100	940	Width of cut—7 ft.
Sweeper, rotary-broom, tractor-mounted, 1-way sweeping	82	*Sweeper only* 96	32	1,100	Broom diameter—30 in. Effective broom width—72 in.
Loader, bucket, tractor-mounted, 1/3-cu-yd, hydraulic.	153	*Mounted* 59	60	*Empty* 4,200 *Loaded* 5,200	*Operating speed (mph).* 1st gear—2.1 2d gear—2.86 3d gear—3.94 4th gear—8.00 Reverse—2.2 Lifting capacity—1,000 lb. Dumping clearance—45 in.
Tractor, crawler-type, Diesel-engine-driven, 35–40 dbhp, w/loader bucket, ¾-cu-yd.	174	*Mounted* 78	123	16,500	Lifting capacity—2,000 lb. Dumping clearance—93 in.
Tractor, wheel, rubber-tired, 23 dbhp, gas-engine-driven, w/Evans clearing unit.	127	*Mounted* 66	78	4,350	Single-line winch pull—100,000 lb. Winch-line speeds—4.76 to 66 fpm.
Tractor, wheel, rubber-tired, 30 dbhp, gas-engine-driven, w/Evans clearing unit.	118 (approx)	*Mounted* 64	66	5,110	Single-line winch pull—100,000 lb. Winch-line speeds—4.76 to 66 fpm.

Table XLV. Physical characteristics of equipment—Continued

Equipment	Over-all Dimensions			Weight (pounds)	Remarks
	Length (inches)	Width (inches)	Height (inches)		
Tractor, wheel, rubber-tired, 23 dbhp, gas-engine-driven, w/Jacques clearing saw and winch.	162	*Mounted* 116	80	6,342	Single-line winch pull—100,000 lb. Winch-line speeds—1.5 to 95 fpm.
Tractor, wheel, rubber-tired, 30 dbhp, gas-engine-driven, w/Jacques clearing saw and winch.	177	*Mounted* 112	84	7,085	Single-line winch pull—100,000 lb. Winch-line speeds—1.5 to 95 fpm.
Auger, earth, skid-mounted, gas-engine-driven.	134	35	54	5,100	Bore-hole diameters—9, 12, 16, and 20 in.
Saw, chain, gasoline powered, 36-inch.	81	21	16	108	
Saw, chain, gasoline powered, 24-inch.	69	21	16	102	

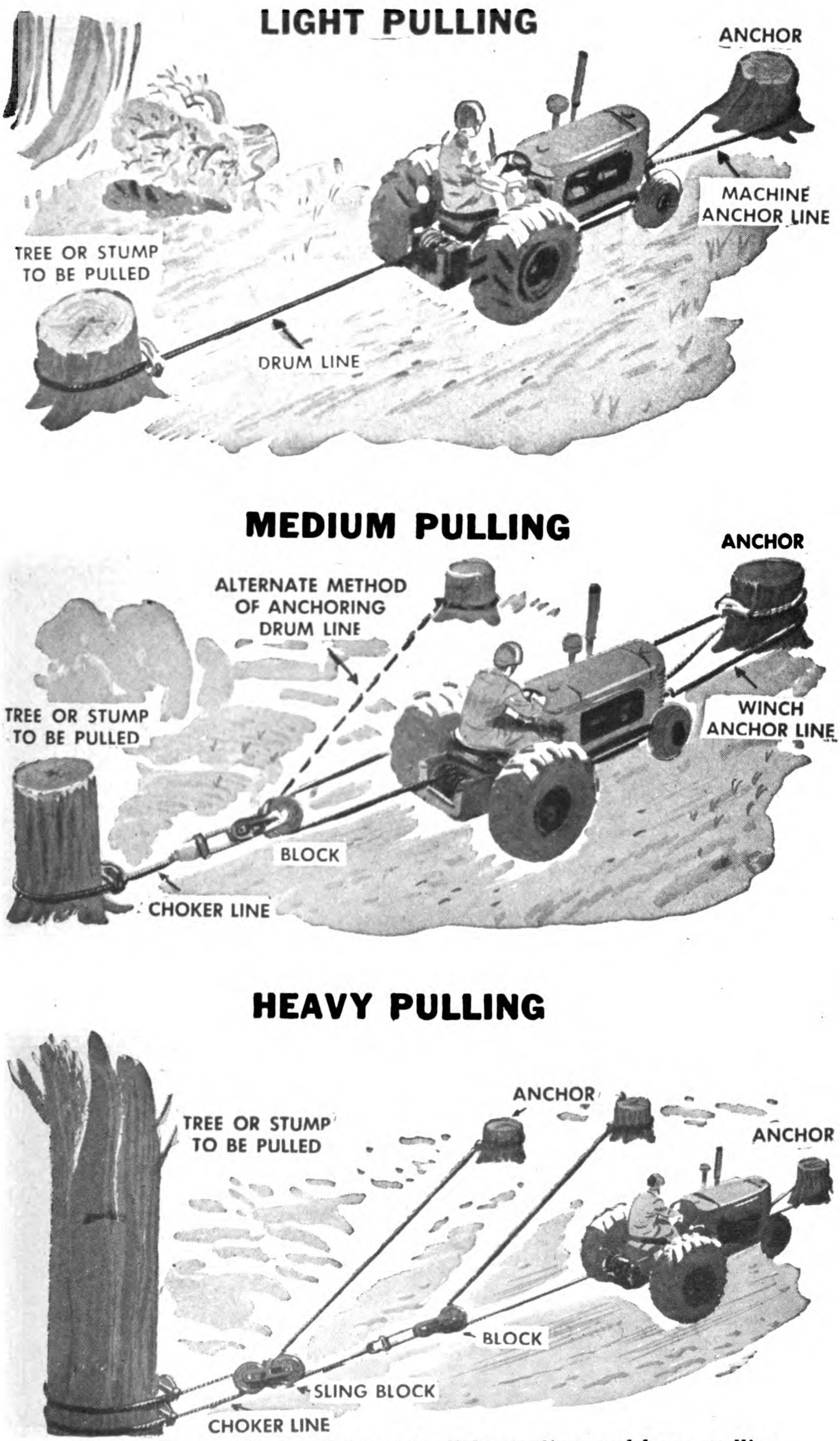


Figure 139. Clearing unit rigged for light, medium and heavy pulling.

Table XLVI. Typical output of ¾-cubic-yard loader bucket

Operation	Haul distance (ft.)	Soil type	Output (cu. yd. per hr.)
Stock-pile loading	--	Sand, gravel, common earth	90
Short-haul excavation	25	Common earth	80
Basement excavation	25 50	Common earth	65 45

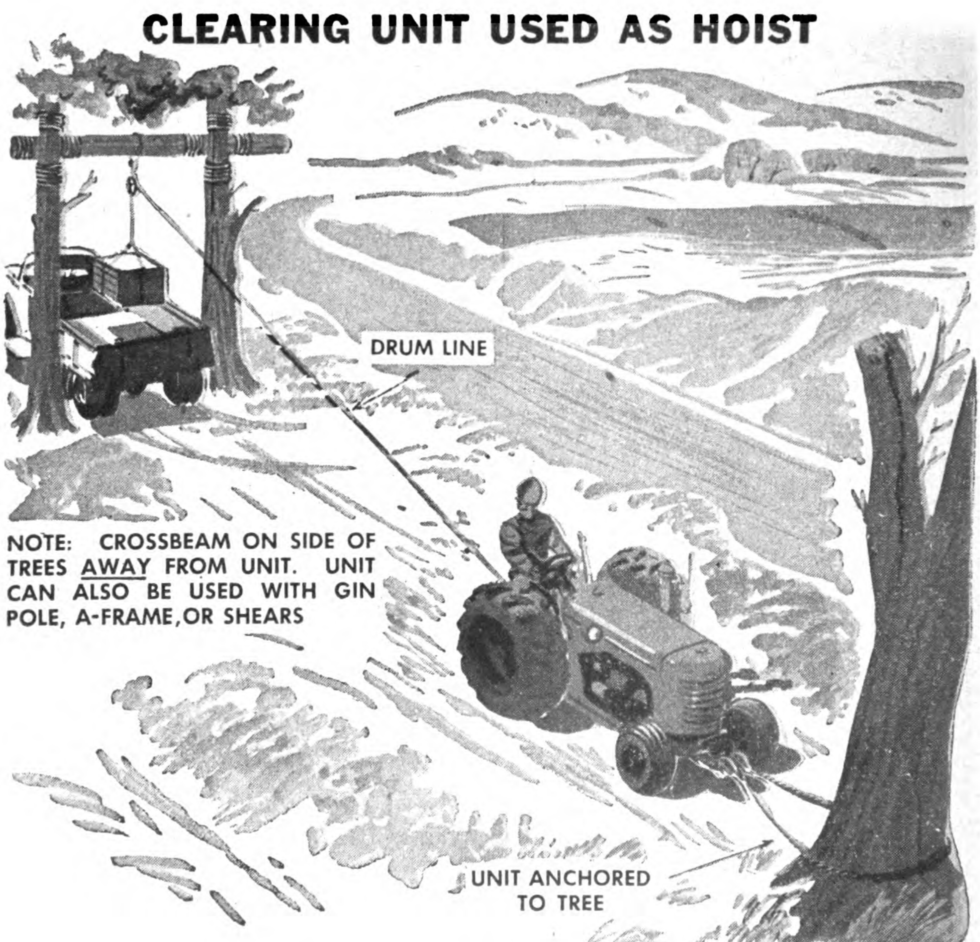
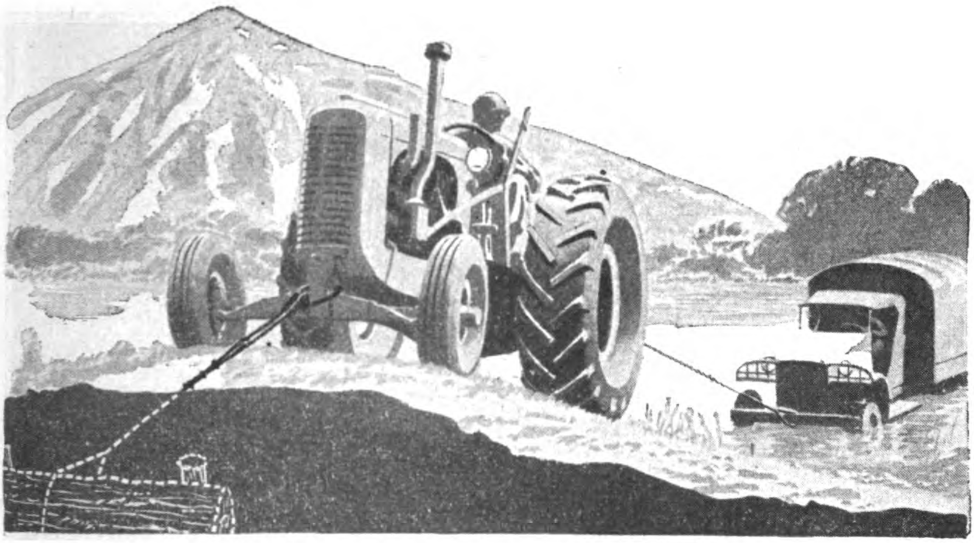


Figure 140. Clearing unit used to hoist heavy object.

EXTRICATING MIRED EQUIPMENT



NOTE: DEADMAN CAN BE USED TO ANCHOR TRACTOR IF TREES ARE NOT AVAILABLE.

Figure 141. Clearing unit used to extricate mired truck.

Table XLVII. Single-line pull of winches

Winch Model	Tractor	Line Pull (lb.)		Line Speed (fpm)	
		Bare Drum	Full Drum	Bare Drum	Full Drum
Evans ECC	D1 (Case)	100,000	100,000	66	113
D4A Hyster	D4 or R4	15,400	8,580	91	164
D4 Hyster	D4	15,400	8,580	91	164
D6N Hyster	D6	25,000	14,000	92	161
D7N Hyster	D7	32,000	22,000	89	127
D8N	D8	53,000	34,000	124	175
CA-1 Braden	CA-1	7,500	3,720	41	88

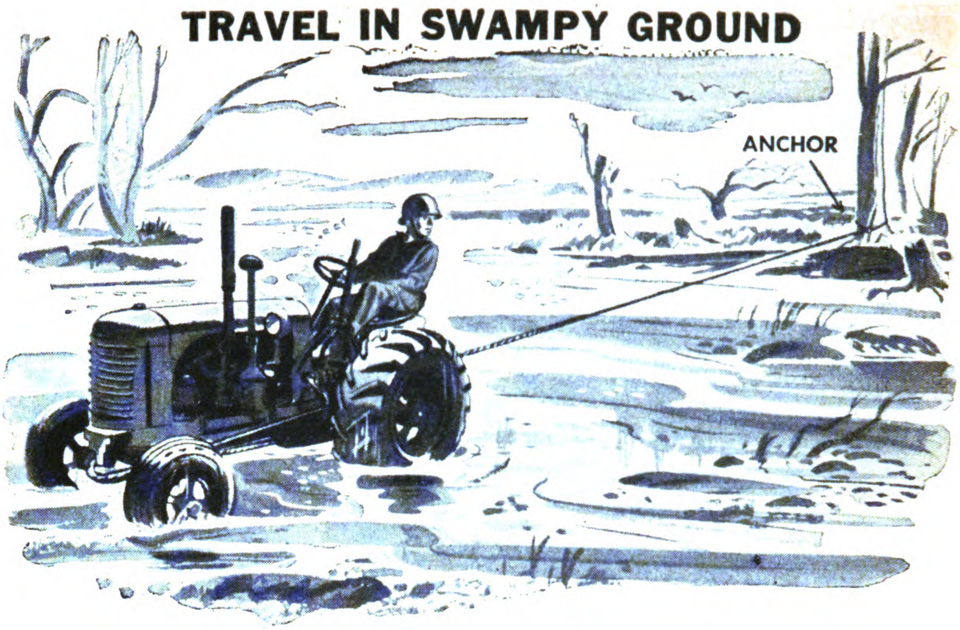


Figure 142. Traveling in swampy or steep terrain.

COMBINED PULLING AND SKIDDING

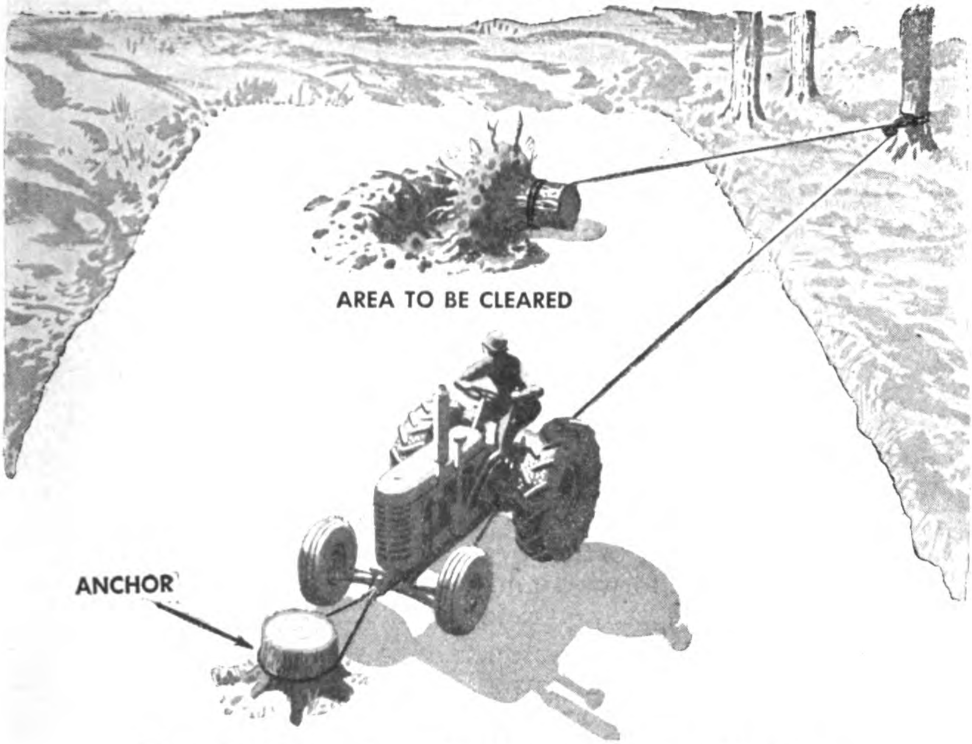


Figure 143. Removing and skidding trees in one operation.

saws are used for felling trees, cutting felled trees into log size, and other similar operations.

(2) *Work output.* There are two sizes of gasoline-powered chain saws, having a maximum cut of 24 and 36 inches respectively. A two-man crew can cut a 20-inch tree in approximately 30 seconds.

CHAPTER 4

CONSTRUCTION AIDS

Section I. GENERAL

70. PURPOSE AND SCOPE. This chapter explains the use of lighting, improvised equipment, explosives, and construction drainage and hydraulic methods as aids to expedite construction operations.

71. LIGHTING. Lighting is generally used during the hours of darkness to aid construction operations. As it is impracticable to flood light entire projects, light is concentrated on areas where work is being done.

a. Pieces of equipment. Each piece of equipment should carry enough lighting for its own needs. (See fig. 144.) All shovels, graders, and tractors should be provided with auxiliary generators, all other items with motor-driven battery-generator arrangements. Graders must have lights for travel forward and backward, light around the blade, and a spot light for spotting grade stakes.

b. Hand labor. Hand-labor operations should have the light concentrated on local areas. Lights should be mounted so they can be shifted quickly from one area to another. A 5-kw generator with 1,000-watt lamps mounted in reflectors on a portable tower (fig. 145) is an excellent unit for this purpose. A dozen or more units of this type are necessary for an average airdrome project.

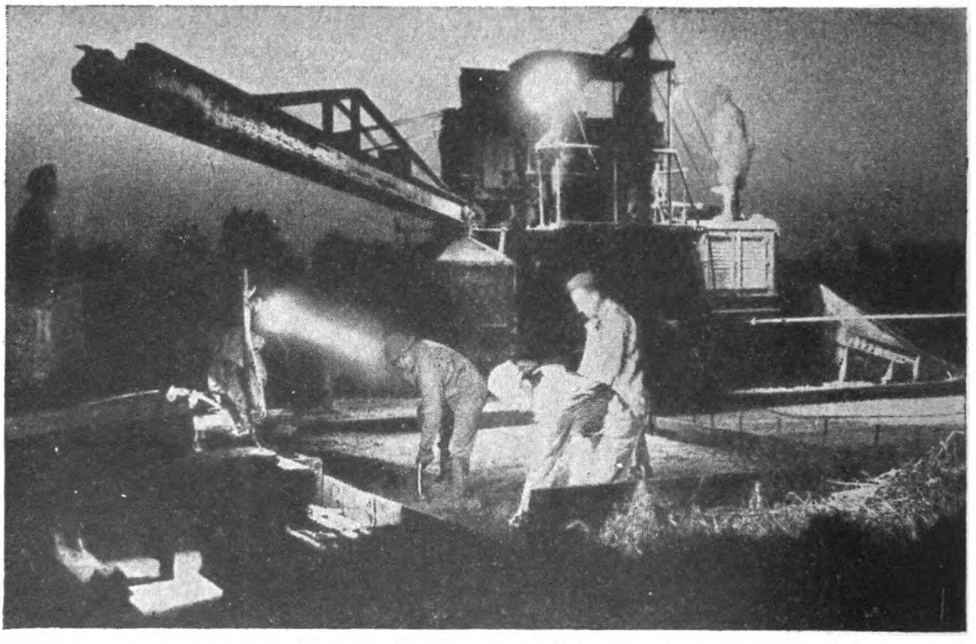


Figure 144. Auxiliary lighting equipment on a 34E paver being used for night work. Note that lights are directed only where needed.

c. Materials plants. Quarries, gravel and soil pits, bituminous-materials plants, concrete-mixing plants, crushing, screening, and washing plants, and stock piles should all be adequately lighted.

d. Traffic. Points of traffic concentration, such as loading and unloading points, must be well lighted.

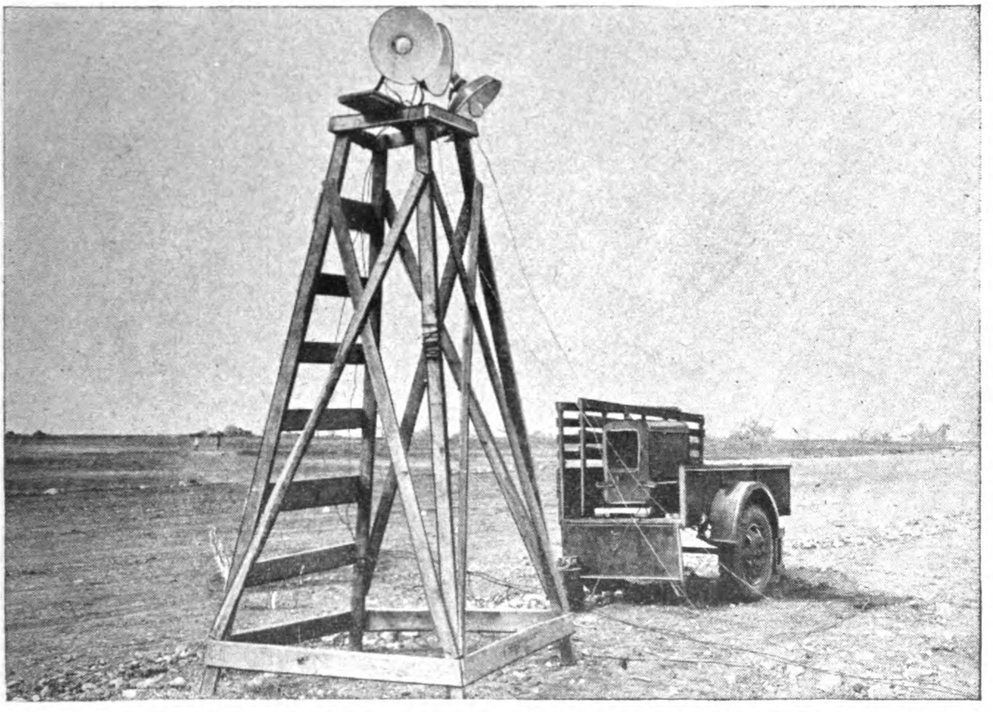


Figure 145. Power plant, 5-kw, and 1,000-watt lamps used to light airdrome during night shifts.

Section II. IMPROVISED EQUIPMENT

72. GENERAL. Improvised equipment listed in this section serves to:

a. Supplement other equipment.

b. Substitute for unavailable equipment.

c. Substitute for equipment on hand that can be better used on other operations.

73. USE OF IMPROVISED EQUIPMENT. Figures 146 through 158 show typical uses of expedient construction aids.

74. ESTIMATING WORK OUTPUT OF IMPROVISED EQUIPMENT.

a. Ramps and traps. Work output of ramps or traps depends on a balance between the number of trucks and the number of dozers or scrapers loading the trucks. If enough trucks are provided, output is governed by dozer or scraper capacity. (See Secs. II and III, ch. 3.)

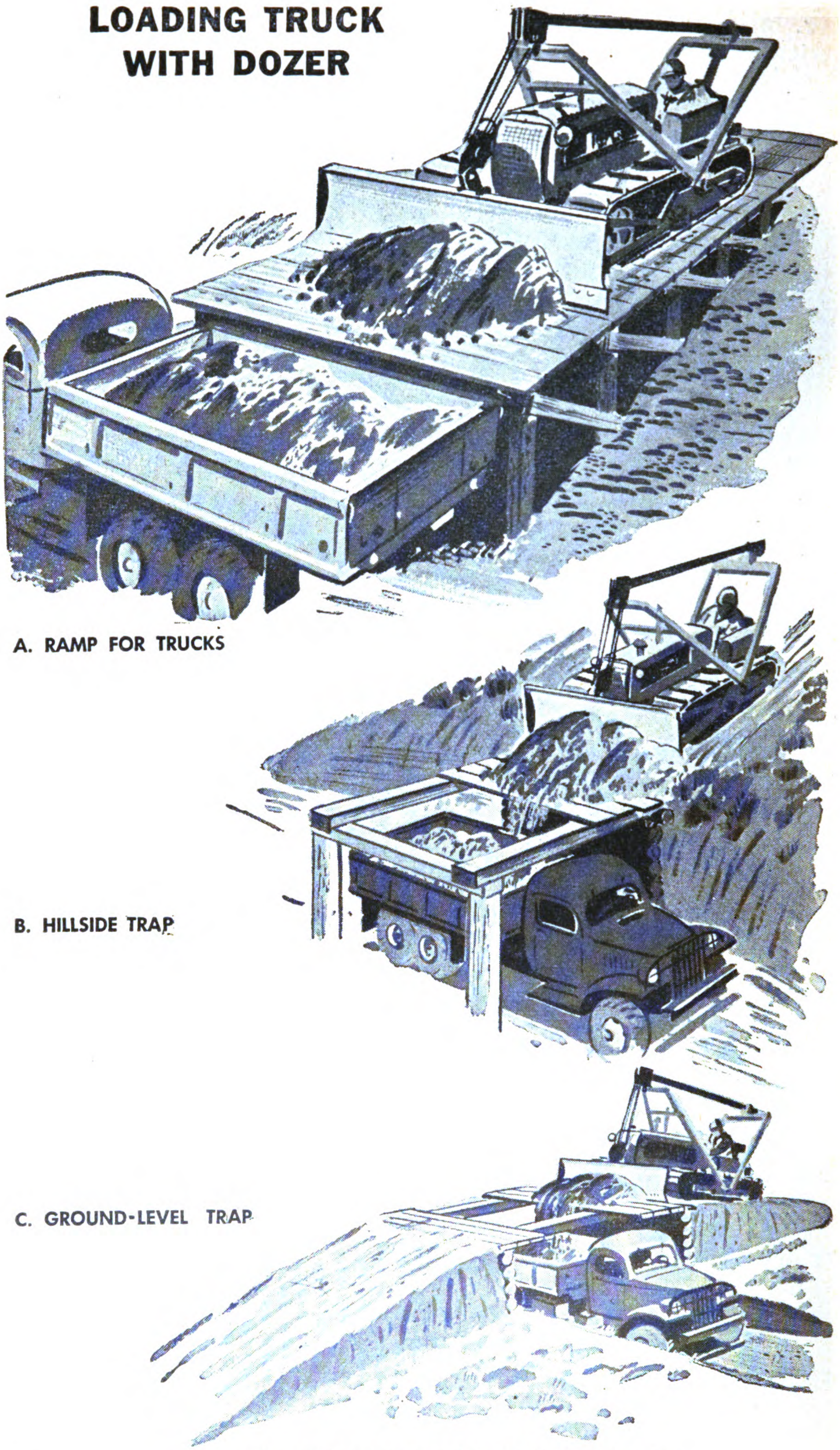


Figure 146. Using ramp and traps to load trucks.

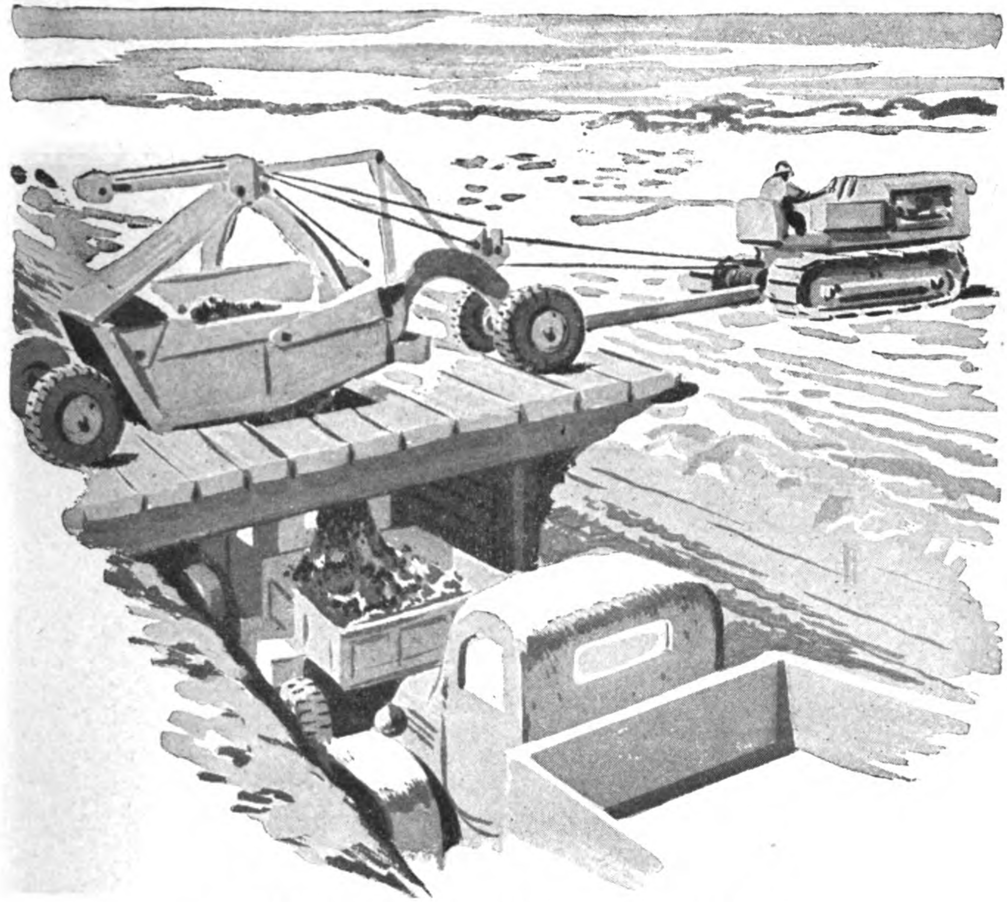


Figure 147. Loading trucks with scraper and trap.

Figure 148. Cargo truck dumping from ramp mounted on another truck.

UNLOADING CARGO TRUCKS

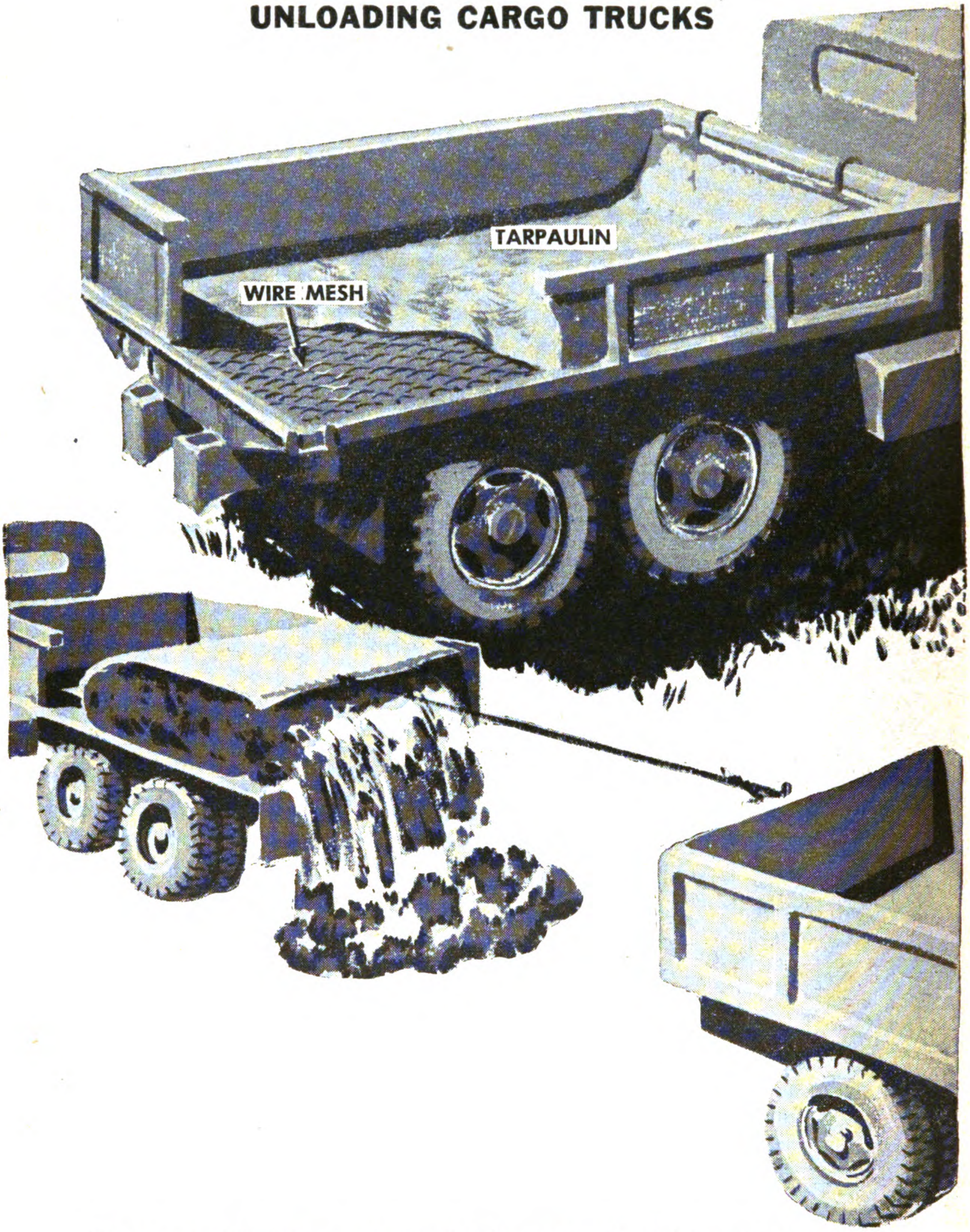


Figure 149. Dumping cargo truck using tarpaulin and heavy ***wire mat.***

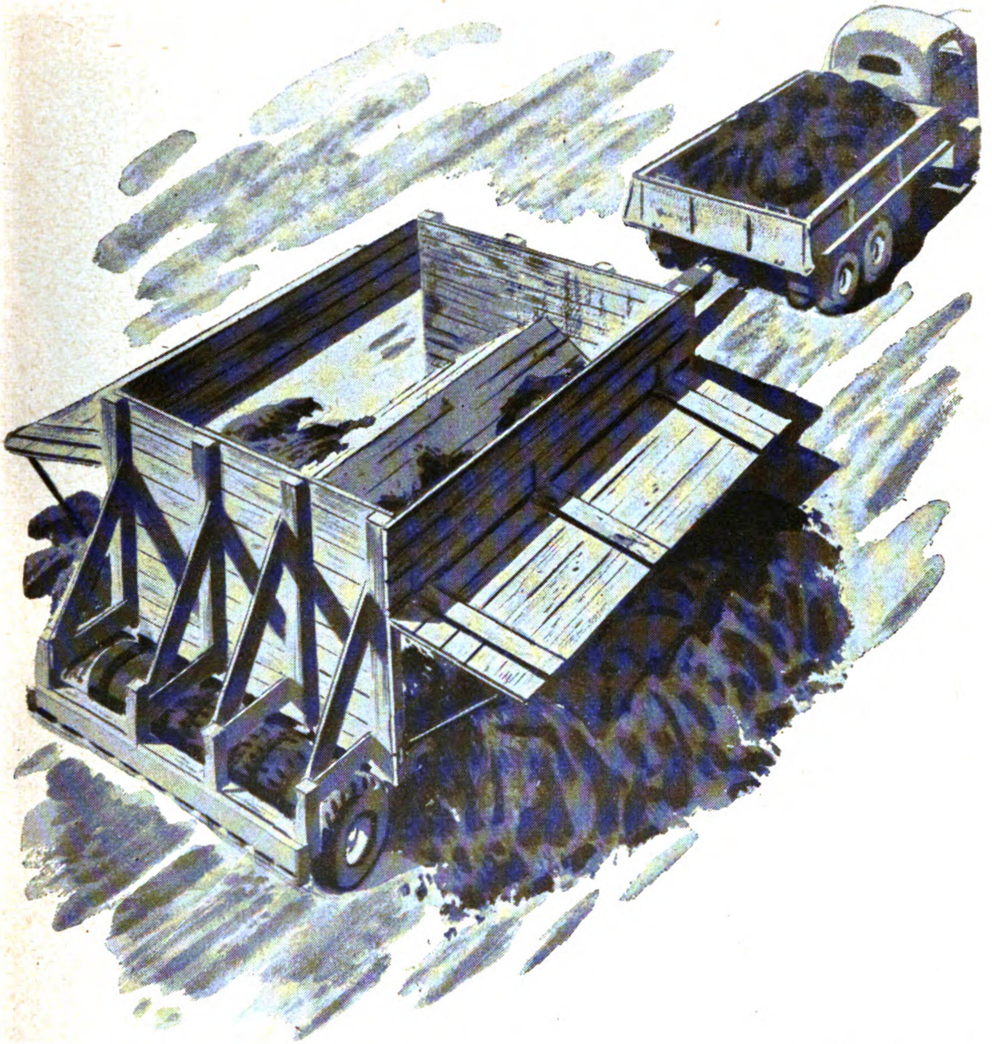


Figure 150. Improvised trailer-mounted box used to haul earth. Inverted V-bottom facilitates unloading.

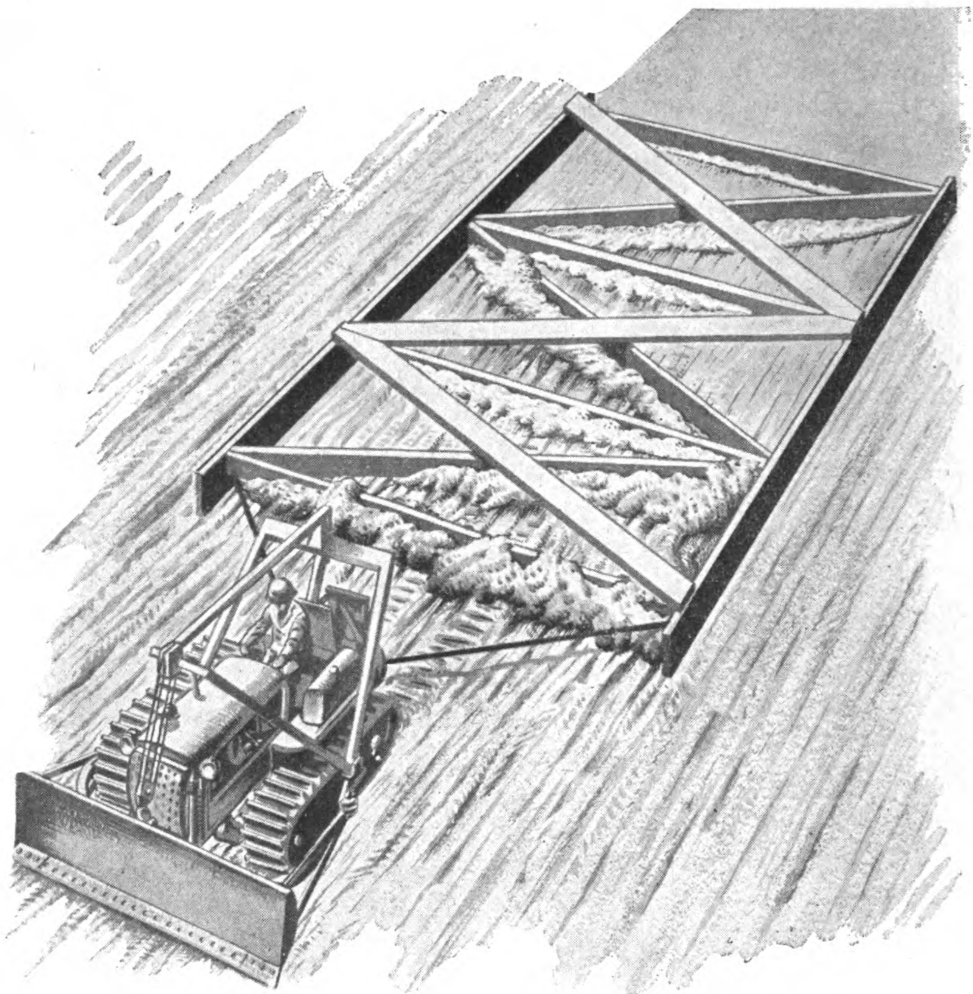


Figure 151. Improvised drag used to spread and level material.

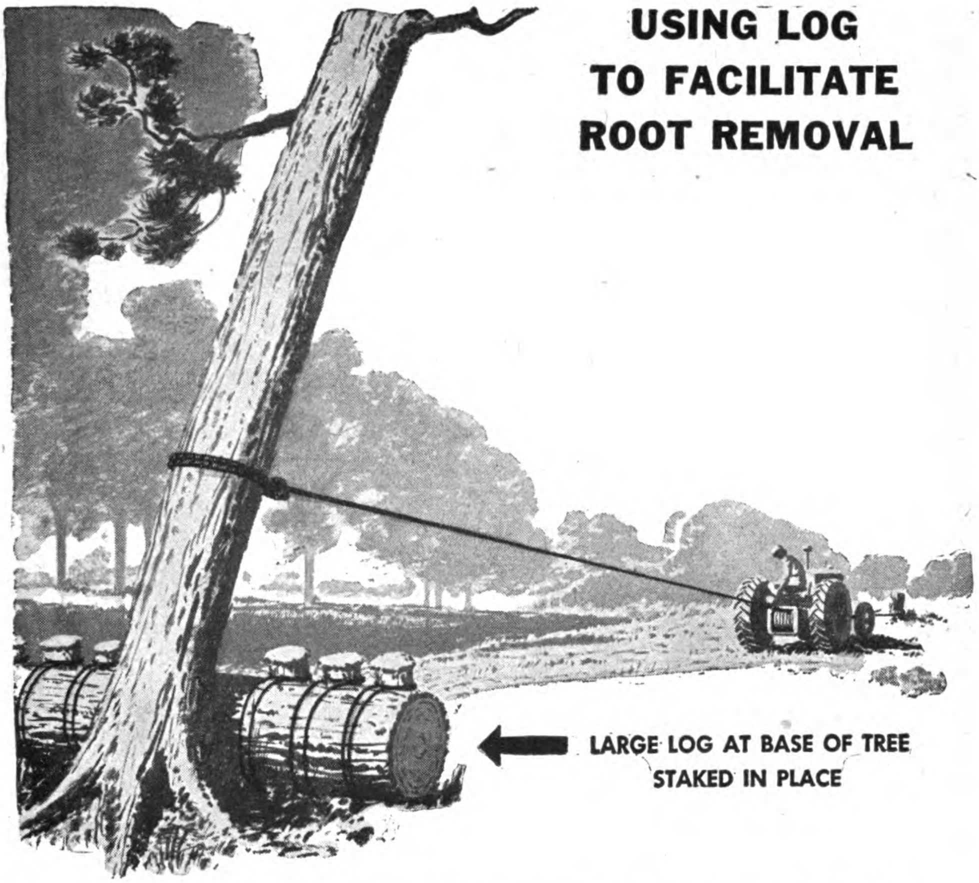


Figure 152. Using log to facilitate root removal in tree clearing operations.

CONSTRUCTION MATS FOR CRANES

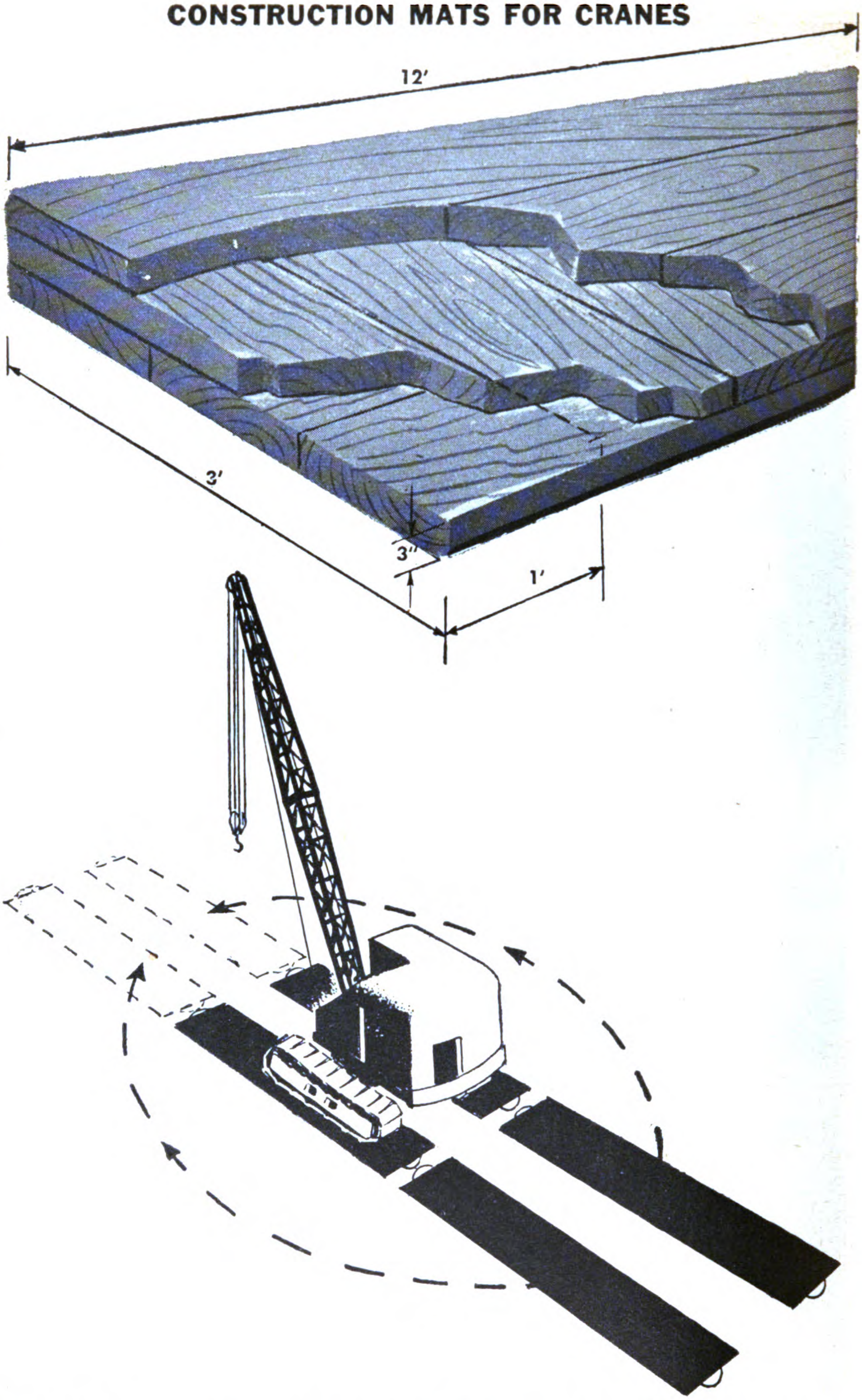


Figure 153. Construction mats used to facilitate crane travel in muddy or swampy terrain.

CABLE LAYING WITH ROOTER

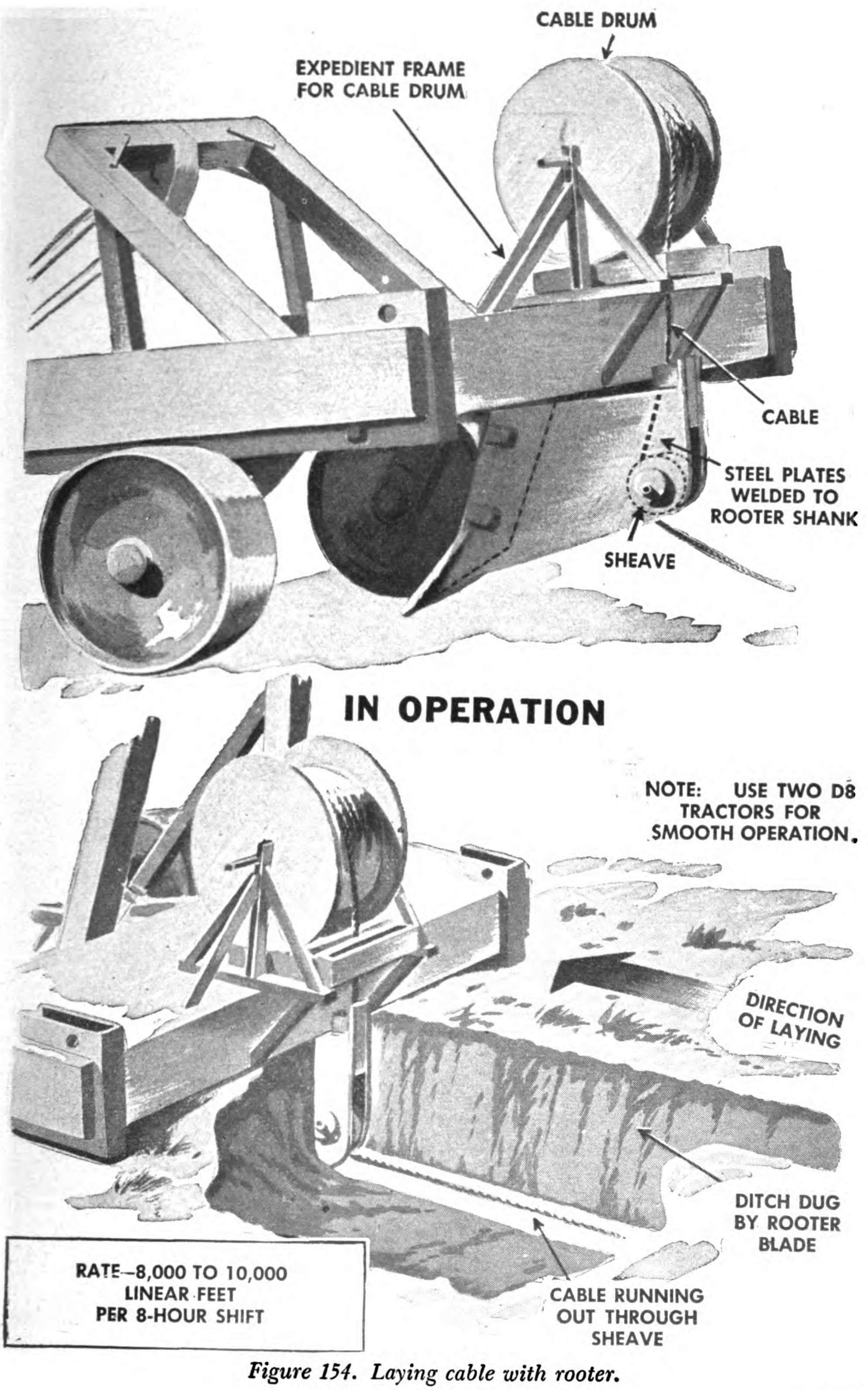


Figure 154. Laying cable with rooter.

WATER SPRINKLER

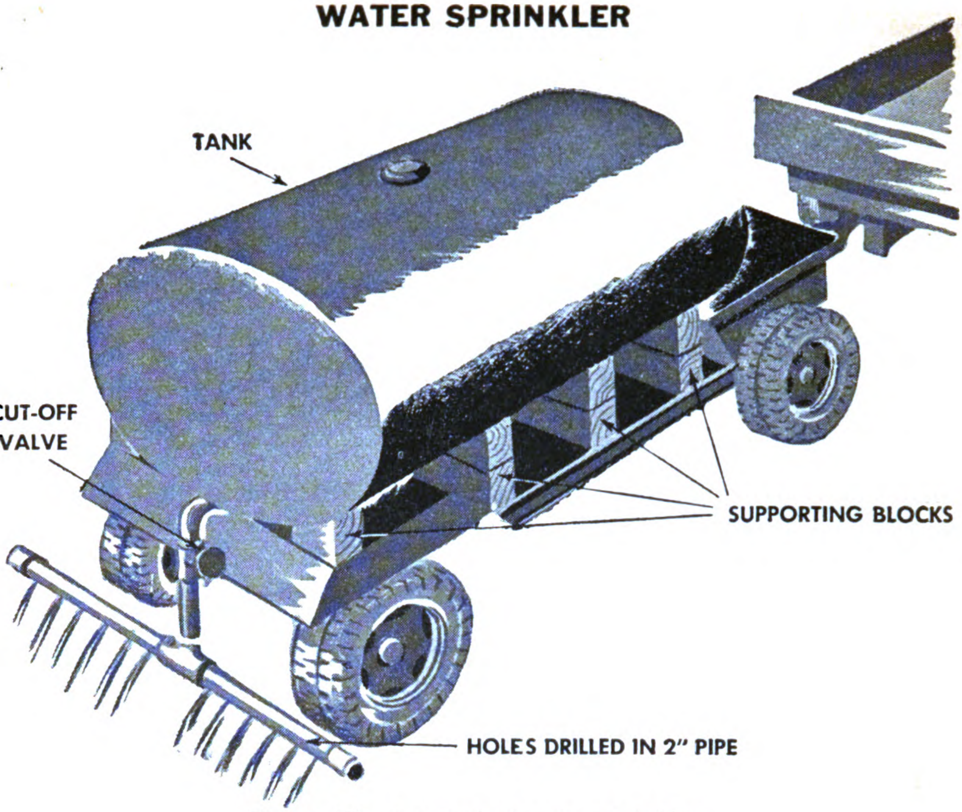


Figure 155. Improvised water sprinkler.

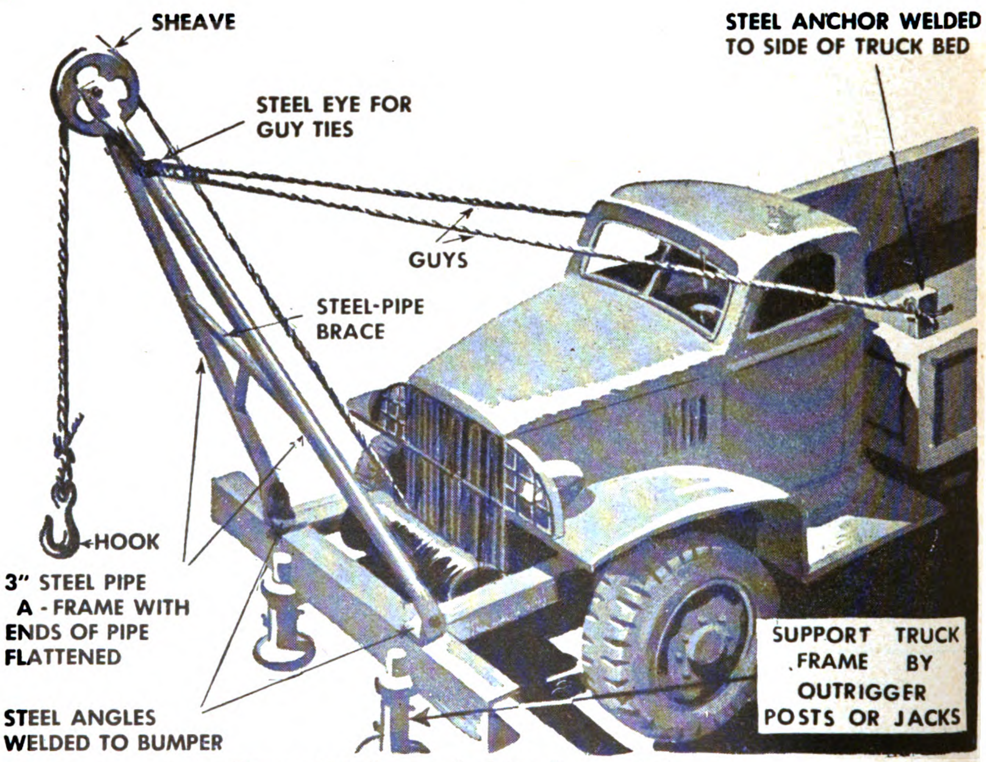


Figure 156. Improvised truck-mounted crane.

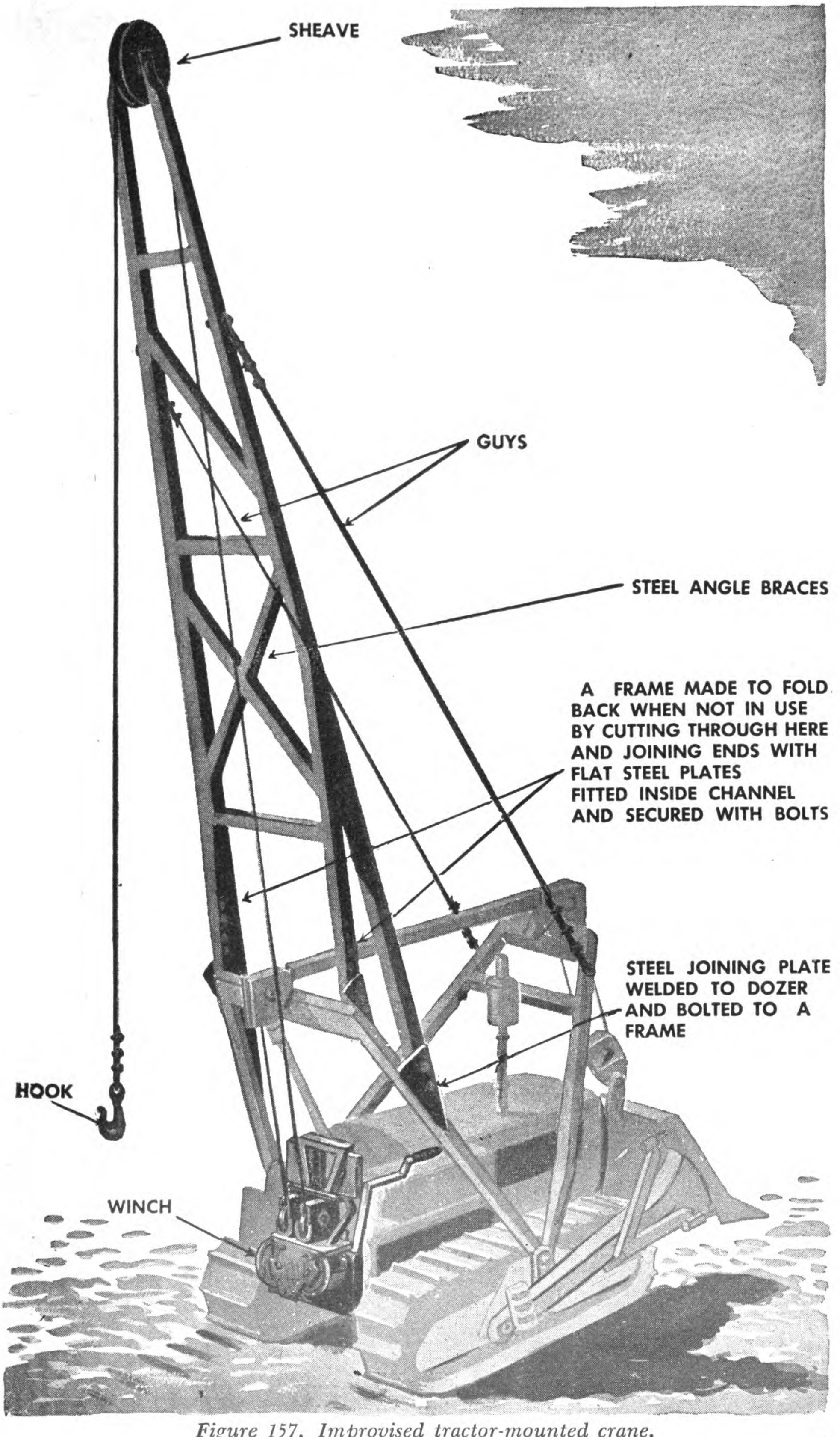


Figure 157. Improvised tractor-mounted crane.

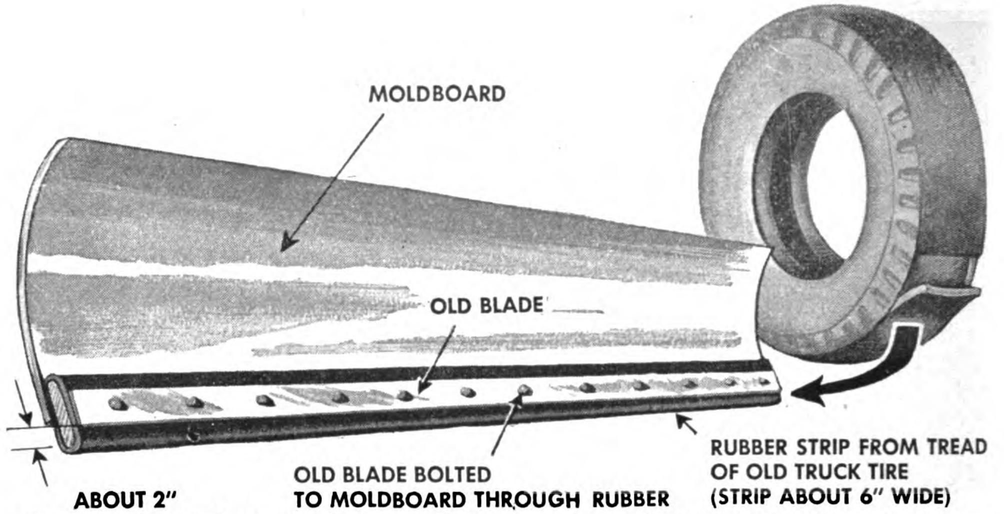


Figure 158. Mud scraper improvised from grader and truck tire and used to clean runway surfaces.

b. Following is a formula to determine the approximate number of trucks required to handle a given dozer or scraper output:

$$N = \frac{Y\ (T + D + L)}{60 \times C \times E}$$

Where, N = number of trucks required.
Y = dozer or scraper output (cubic yards per hour).
60 = minutes per hour.
T = travel time in minutes.
L = loading time in minutes.
D = dumping time in minutes.
C = capacity of individual truck in cubic yards.
E = efficiency factor.

Adjustment should be made after operation begins to obtain an exact balance between excavating and hauling equipment.

Example problem: $Y = 300$ cubic yards per hour
Travel speed (empty) = 20 mph
Travel speed (loaded) = 10 mph
$C = 2\frac{1}{2}$ cubic yards
$L = 2$ minutes
$D = 1$ minute
$E = 0.80$
Haul distance = ½ mile (2,640 feet)

Step I. Calculate travel time.

$$\text{Travel time} = \frac{2{,}640}{\frac{20 \times 5{,}280}{60}} + \frac{2{,}640}{\frac{10 \times 5{,}280}{60}}$$

$$= 1\tfrac{1}{2}\ \text{min} + 3\ \text{min} = 4\tfrac{1}{2}\ \text{min}$$

Step II. Substitute values in formula.

$$N = \frac{300\ (4\frac{1}{2} + 1 + 2)}{60 \times 2\frac{1}{2} \times 0.80}$$

$$N = 18.75\ \text{(19 trucks)}$$

75. CHARACTERISTICS OF EXPLOSIVES. Table XLVIII lists the characteristics of explosives and their use and relative value in road and airdrome construction. FM 5–25 gives detailed information on handling, storing, and transporting explosives; on preparation, calculation, and placing of charges; and on demolition equipment.

76. QUARRYING. a. Purpose. Quarrying is used to obtain rock for crushing and processing to the size required. Rock is loosened and broken up by blasting. To facilitate crushing and handling, the rock should be thoroughly blasted.

b. Quarrying methods. (1) *Benching* (fig. 159). In benching, the face of the quarry is worked by benches up to 20 feet high. Pneumatic or wagon drills are used to drill vertical holes 6 to 8 feet back from the face. The holes are spaced 4 to 6 feet apart in single or double rows and are filled at least half full of explosives and tamped full. In most rocks, 40 percent dynamite is used. In hard rock such as trap rock and granite, 60 percent dynamite is used, and holes are drilled 2 feet deeper than the terrace face and loaded to the weight listed in table XLIX. Holes are sprung (see snake hole below) and then all charges are fired simultaneously.

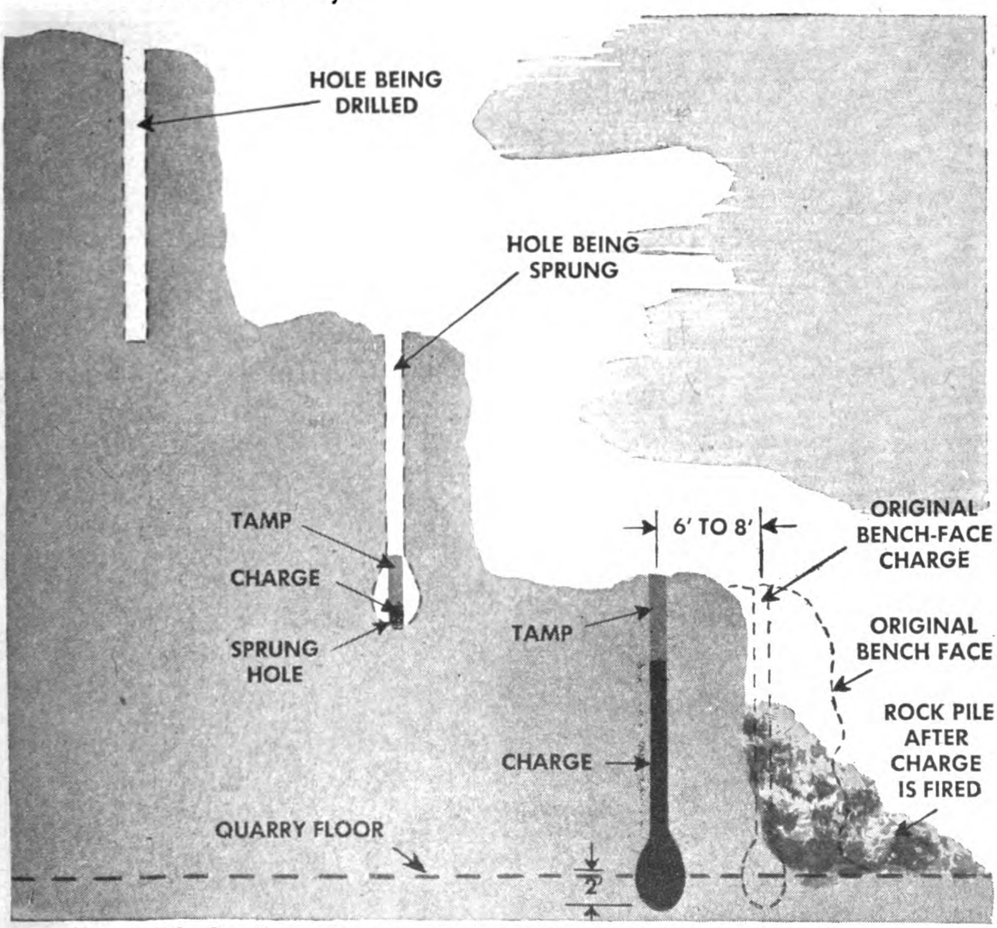


Figure 159. Benching showing steps of drilling, placing charge, and clearing.

(2) *Snakeholing* (fig. 160). Snakeholing is used on faces up to 60 feet high where part of the face can be drilled while the rest is being cleared. It is used in massive formations or where rock has vertical stratification. Holes are drilled 3 to 4 feet above the base of the quarry face and slanted to bring the point of the hole when sprung (FM 5–25) level with the quarry floor. Length of drilled holes should be half the height of the face. They are drilled with pneumatic rock drills and are spaced 8 to 10 feet apart. The end of the holes are sprung five or six times, increasing the charge with each shot. The final charge varies from 150 to 500 pounds depending on the overburden. It is loaded into the sprung hole, and the shank of the hole is tamped full. In most rock, 40 per cent dynamite is used for springing and final blasting. In hard rock, 60 per cent dynamite should be used. Holes are fired simultaneously.

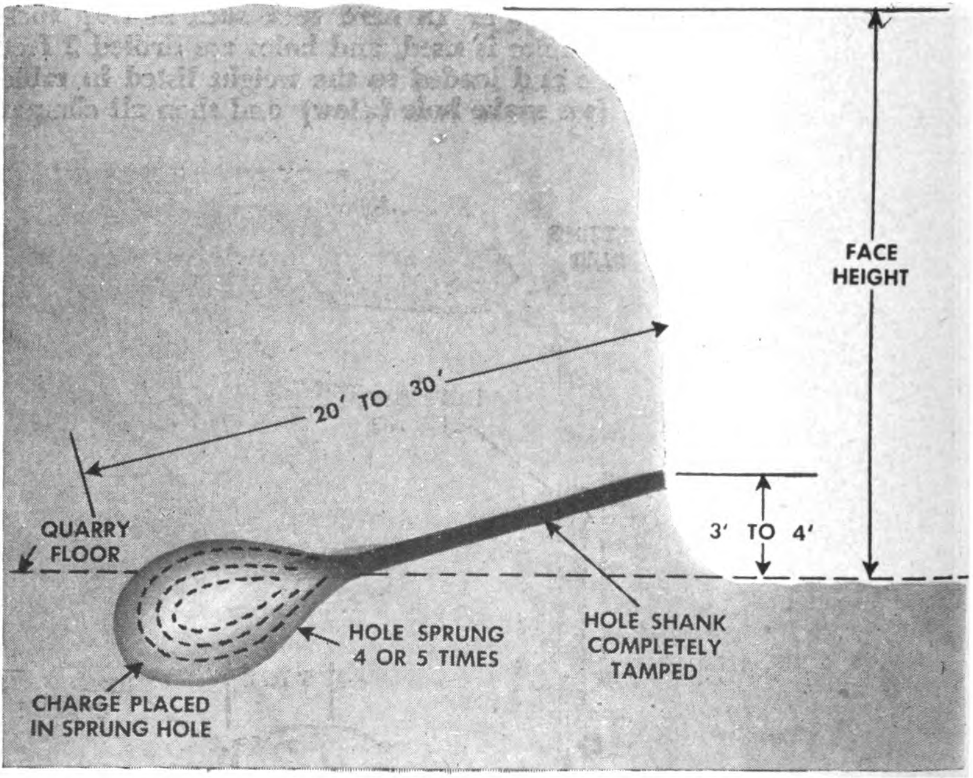


Figure 160. Snakeholing, showing steps in drilling, springing, and clearing.

(3) *Well-drill blasting* (fig. 161). (*a*) Well-drill blasting is used on 30- to 120-foot faces where rock strata are not steeply inclined and will not cause the drill to bind. Holes are drilled 2 feet deeper than the quarry floor and 4 to 6 inches in diameter for limestone or 6 to 8 inches in diameter for hard rock. Holes are then sprung. Wagon drills and well-drilling equipment can be used to drill bore holes. The

Table XLVIII. Characteristics and use of military explosives[1]

Name	Velocity of detonation (feet per second)	Size of each unit (inches)	Smallest cap required for detonation	Underwater stability	Intensity of poisonous fumes (inclosed)	Value in construction work: Quarry and rock excavation	Ditching	Underfilling	Tree and stump blasting
TNT ½-lb block 1-lb block	21,000	1¹⁵⁄₁₆ x 1¹⁵⁄₁₆ x 3¹¹⁄₁₆ 1¹⁵⁄₁₆ x 1¹⁵⁄₁₆ x 7	CE special blasting cap	Good	Dangerous	Fair	Poor	Poor	Fair
Ammonium[2] nitrate (40-lb cratering charge)	11,000	Can 8¼ dia 17 high	CE special blasting cap	Excellent	Dangerous	Good	Poor	Good	Poor
Nitrostarch ¼-lb ½-lb 1-lb package	15,000	1¼ x 1¼ x 2½ 1¼ x 2½ x 2½ 2½ x 2½ x 2½	CE special blasting cap	Good	Dangerous	Fair	Poor	Poor	Fair
Composition C ½-lb blocks	26,000	Plastic, can be molded to any shape.	Two CE special blasting caps.	Excellent	Dangerous	Fair	Fair[3]	Fair	Fair
Composition C-2 or C-3 ½- and 2¼-lb block	26,000	Plastic, can be molded to any shape.	CE special blasting cap	Excellent	Dangerous	Fair	Excellent[3]	Fair	Fair
Tetrytol 8 2½-lb blocks on a chain	23,000	2 x 2 x 11	CE special blasting cap with primacord	Excellent	Dangerous	Poor	Excellent[3]	Poor	Fair
BRITISH: Wet gun cotton	21,000	6 x 3 x 1½ (slabs)	British primer pellet	Good	Dangerous	Poor	Poor	Poor	Poor
BRITISH: Ammonal 25 lb	9,000	9 x 9¼ x 9 (tins)	British primer pellet	Good[2]	Dangerous	Fair	Poor	Poor	Poor
BRITISH: 808	21,000	1⅜ x 3 (cylindrical cartridges)	British primer pellet	Excellent	Moderate	Good	Good[3]	Good	Good

See footnotes at end of table.

Table XLVIII. Characteristics and use of military explosives[1]*—Continued.*

	Name	Velocity of detonation (feet per second)	Size of each unit (inches)	Smallest cap required for detonation	Underwater stability	Intensity of poisonous fumes (inclosed)	Value in construction work: Quarry and rock excavation	Value in construction work: Ditching	Value in construction work: Underfilling	Value in construction work: Tree and stump blasting
DYNAMITE (½-lb cartridge)	Straight 40% 50% 60%	 15,000 18,000 19,000	1¼ dia 8 long	No 6 commercial cap	Fair	Moderate	Good	Excellent 50% and 60% Fair[3] 40%	Good	Good
	Ammonia (extra) 40% 50% 60%	 9,000 11,000 12,000	1¼ dia 8 long	No 6 commercial cap	Poor	Dangerous	Good[4]	Fair[3]	Fair[3]	Good
	Gelatin 40% 50% 60% 75%	 8,000 9,000 16,000 17,500	1¼ dia 8 long	No 6 commercial cap	Excellent	Safe	Excellent	Excellent[3]	Excellent	Excellent
Blasting gelatin		20,000	1¼ x 8 and 6 x 24 cartridges.	No 6 commercial cap	Excellent	Moderate	Good[5] Fair[6]	Excellent[3]	Good	Fair

[1] *a.* The best all-purpose explosives for quarrying and construction operations are 40 or 60 percent gelatin dynamite.
b. There are two important rules for detonation by electric circuits.
(1) Never mix cap brands.
(2) Always check for short in lead lines.
c. Space holes evenly wherever possible. Confine charge as much as possible by good tamping or cover.
d. In blasting for a specified depth, add 10 percent to length of bore hole.

[2] Ammonium nitrate and ammonal must not be removed from can.

[3] Must be shot with each bore hole primed.

[4] For dry work only.

[5] Hard rock.

[6] Soft rock.

depth of bore holes should be controlled with a level or transit. The spacing of holes is listed below:

Face height (feet)	Distance back of face (feet)	Spacing (feet)
30-40	15	12
40-50	18	14
50-90	20	16-18
90-120	25	20

(*b*) Four or five rows of 30- to 40-foot holes can be shot at one time. Two rows of 40- to 50-foot holes can be shot at once. For faces more than 50 feet high, only one row of holes is fired.

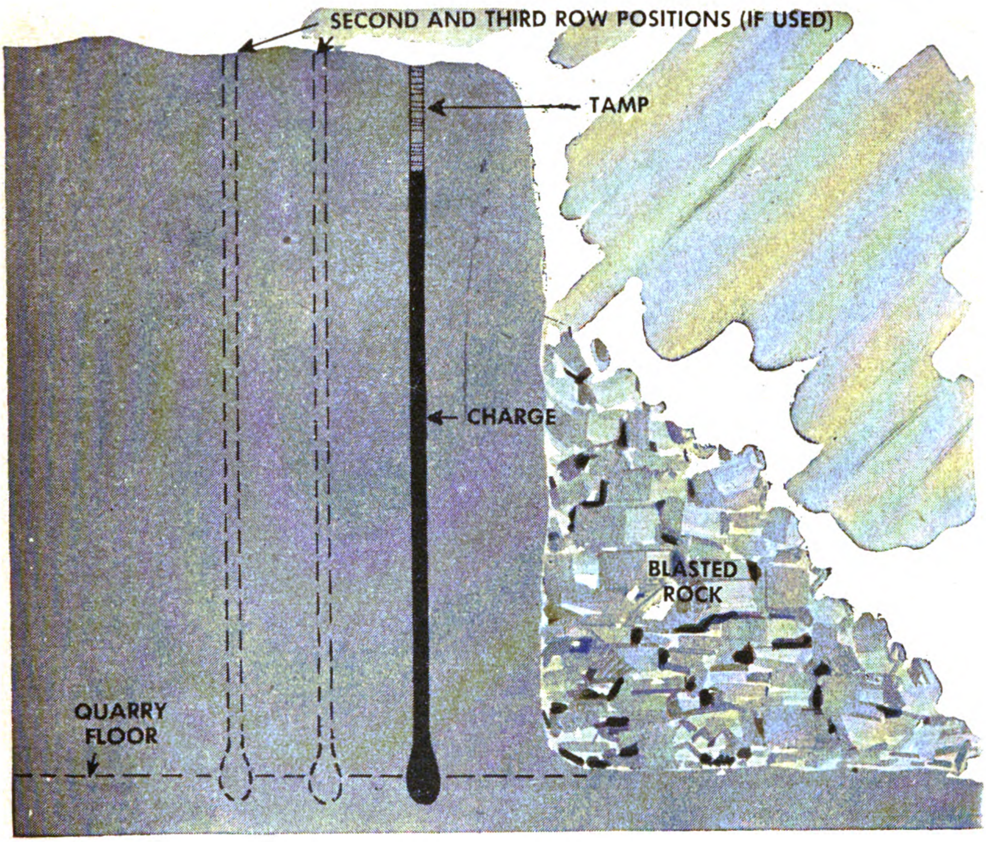


Figure 161. Well-drill blasting.

c. Amount of explosives used. (1) The amount of explosives used varies with the hardness of the rock, the number of cracks and fissures, and the quarrying method used. In general, test holes and test blasts are the only certain method of determining the amount of explosives required.

(2) Table XLIX lists the approximate amount of explosives used in benching and well-drilling bore holes.

Table XLIX. Approximate explosives required per foot of hole (well-tamped)

Diameter of bore hole (inches)	Explosives (pounds per foot of hole)	Diameter of bore hole (inches)	Explosives (pounds per foot of hole)
1	0.30	5	7.40
1¼	0.45	5½	8.30
1½	0.65	5⅝	9.35
1¾	0.90	6	10.60
2	1.20	6½	12.50
2½	1.85	7	14.50
3	2.70	8	18.90
3½	3.65	9	23.90
4	4.75	10	29.50
4½	5.95	11	35.70
		12	42.50

77. ROCK EXCAVATION. Rock making shovel excavation difficult or impossible in road cuts must be blasted.

a. Overburden. Soft or easily excavated overburden deeper than 6 feet is usually removed before blasting the rock. It is more efficient to blast the entire formation if the overburden is less than 6 feet deep.

b. Depth of blasted layers and excavation steps. Cuts should be made in 8- or 10-foot steps. Figure 162 shows a method which can be used on all cuts deeper than 10 feet. It shortens the shovel swing and provides continuous truck routes.

c. Spacing of bore holes. (1) *Well holes.* An entire cut can be blasted to grade with one shot by drilling well holes ahead of the shovel. (See fig. 163.) This speeds shovel operation. When the whole cut cannot be blasted at once, bore holes should be drilled 100 to 150 feet ahead of the shovel and blasted four or five rows at a time.

(2) *Snake holes.* Snake holes are usually used to widen cuts. They are drilled on 5-foot centers and wherever possible blasted simultaneously. (See fig. 163.)

d. Sidehill cuts. A method of making sidehill cuts is shown in figure 164. Well holes are drilled 5 to 8 feet apart in rows spaced 5 to 8 feet apart.

e. Amount of explosives. The weight of explosives put in each bore hole varies with the type and condition of material to be blasted and the degree of break-up necessary for efficient shovel operation. Table XLIX lists the amount of explosives bore holes will take per foot of hole. Test bore holes should be used to determine the total weight of explosives required. Generally, each test bore hole indicates

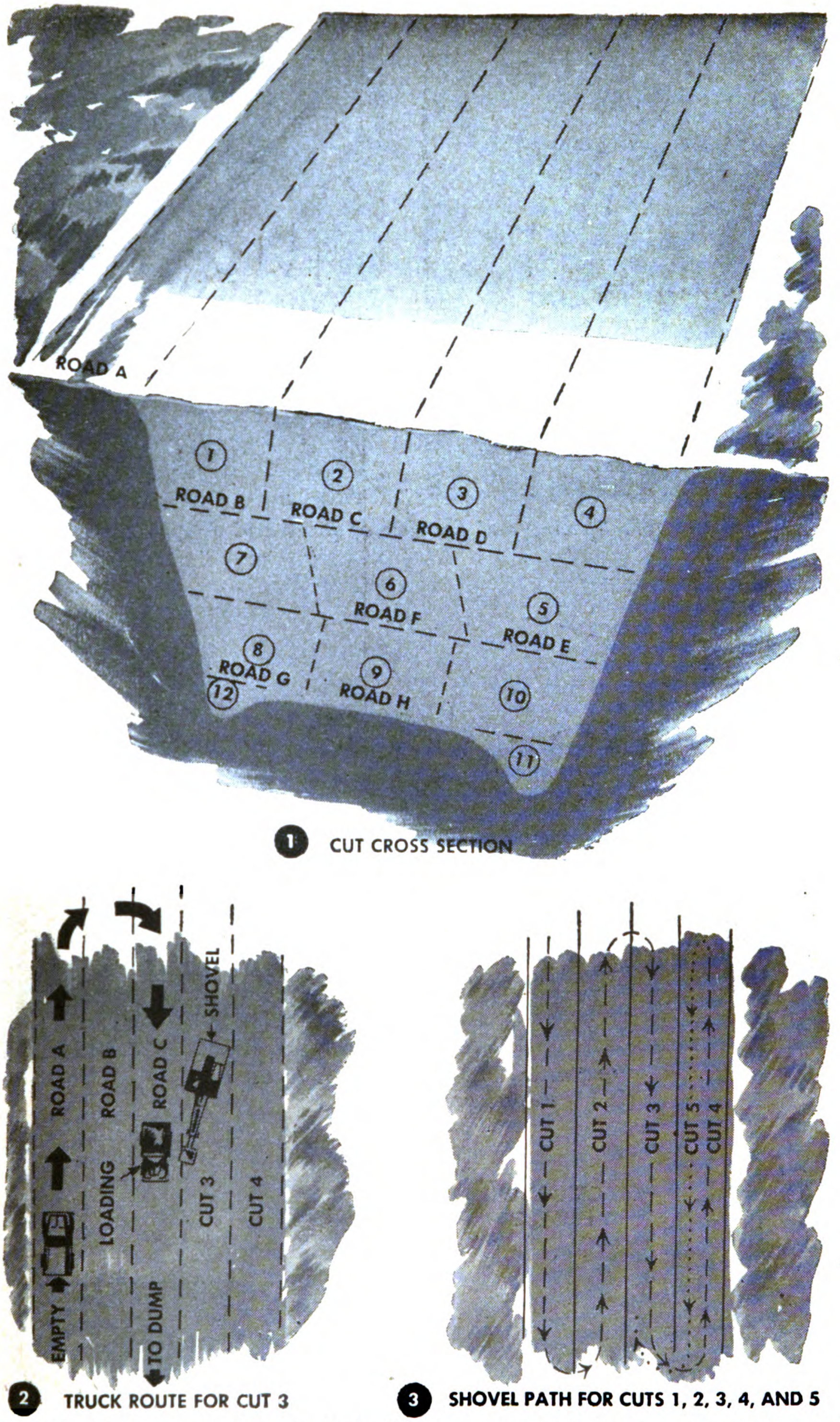


Figure 162. Rock excavation by shelved cuts; shovel and truck method of clearing a 30-foot cut. The shovel works against blasted face in cut 1 and loads rock into trucks on road A. Shovel then works in cut 2 with loaded trucks traveling on road B in cut 1. This continues for cuts 3 and 4. Then shovel works in cut 5 and loads into trucks on road D. Cuts 6 and 7 are made and shovel is shifted to trough 8, and 8, 9, and 10 are cleared. Ditches 11 and 12 can be cleared out with small backdigger or shovel.

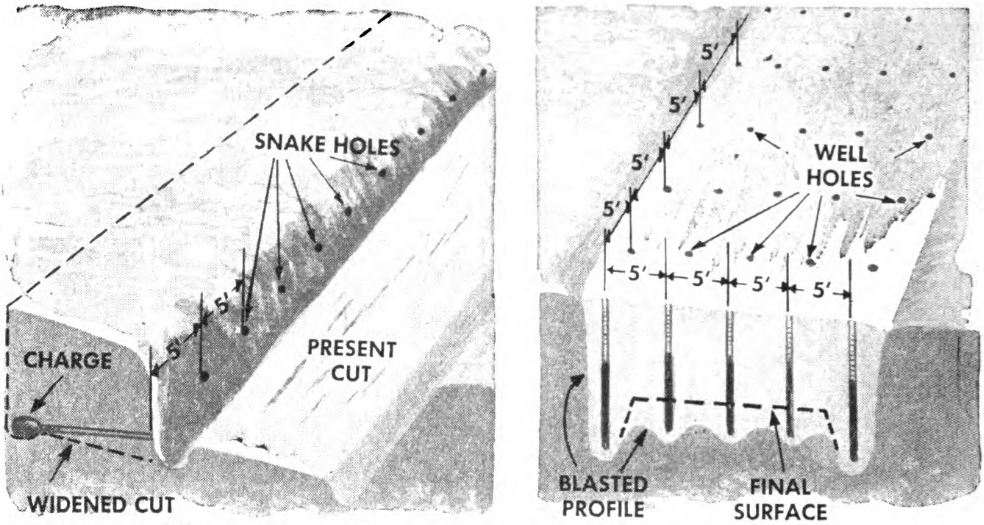
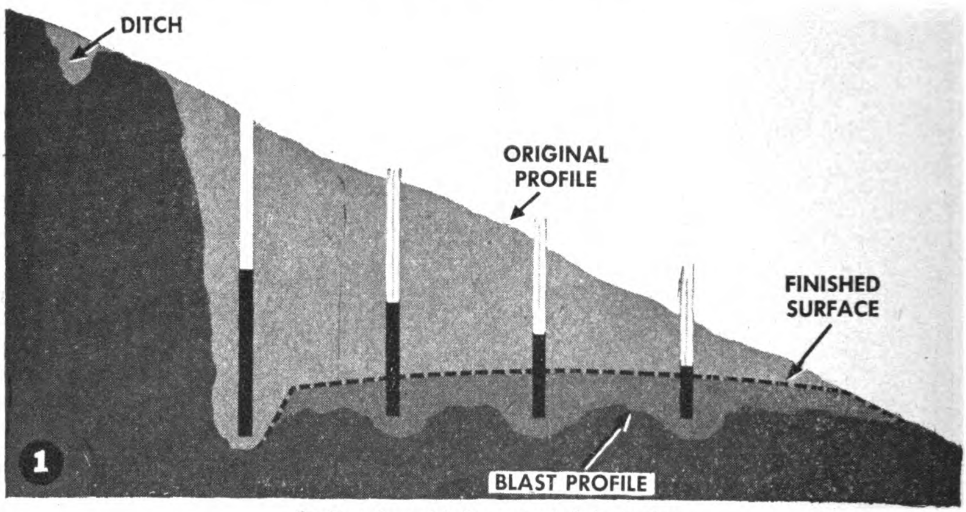
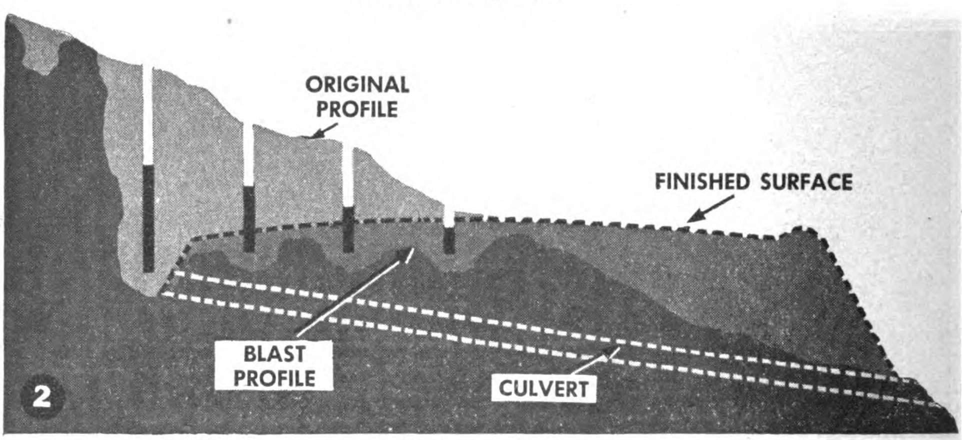


Figure 163. Spacing and position of snake and well holes.



① *Cut in which material is to be wasted or hauled.*



② *Cut and fill.*

Figure 164. Sidehill cuts.

slightly different characteristics caused by rock fissures or tamping. For best results a 10 to 20 percent overload is necessary. This will make shovel operation faster and will minimize redrilling and reshooting.

78. DITCHING. a. General. Open ditches can be blasted in rock and most-type soils by either the propagation or electrical method. These methods are not effective in gravel, loose sand, or hard-packed dry earth. Ditches can be blasted from 2½ to 12 feet deep and from 4 to 40 feet wide, depending on the loading method and the amount of explosive used. Blasting cuts a rough ditch which may be improved and cleaned with a grader or dozer, and eliminates large soil piles along the sides of the ditch.

b. Propagation method. (1) *General.* The propagation method is used only in wet soils. It cannot be used in loose sand or gravel or in hard-packed dry earth. In this method, the hole or holes at the end of the proposed ditch are primed. The concussion from each charge is sufficient to detonate succeeding charges. This method is especially good in swamps where the ground is covered by several inches of water and contains stumps.

(2) *Test shots.* Make a few trial shots to ascertain the best depth and spacing for holes. Generally, for ditches 3 to 3½ feet deep, charges should be placed 2 to 2½ feet deep and spaced 18 to 24 inches apart. In swamps the charge should be placed 1 to 2 feet above the desired bottom of the ditch. In no case are charges placed more than 24 inches apart. Begin with holes 2 feet deep and 18 inches apart. One extra charge should be placed in the primer hole and in each hole adjoining the primer. Correct loading will lift the soil at least 200 feet leaving a clean ditch.

(3) *Amount of charge and size of ditch.* In soil with few roots, small ditches about 2 feet deep and 4 feet wide are dug with ½-pound charges spaced 18 inches apart. Larger ditches are dug with 2- or 4-pound charges in each hole. A second and third line of charges parallel to and 4 to 5 feet from the first line are used to make wide ditches. Each line of charges *must be primed* and it is advisable to overload the first or primed charge 1 or 2 pounds.

(4) *Charge holes.* The holes are bored along the ditch center line as shown in figure 165. The charge line can be run with a transit or chalk line. When using a transit, the grade of the trench can be accurately controlled by checking the hole depth every 5 or 10 holes and at each change in grade. (See fig 166.) Holes are put down using a sharp punch or a quicksand punch. (See fig 167.) Holes are loaded and tamped at once to prevent cave-ins and to insure that the charge is at the correct depth.

c. Electrical method. (1) *General.* The electrical method of blasting does efficient work regardless of moisture content of the soil. In this method, each charge is primed with an electric blasting cap. A high-velocity explosive should be used to obtain clean ditches. *Blasting ditches in dry sand and fine gravel is practically impossible.*

(2) *Amount of charge and methods of loading.* The amount of charge for various sized ditches can be determined by the test method

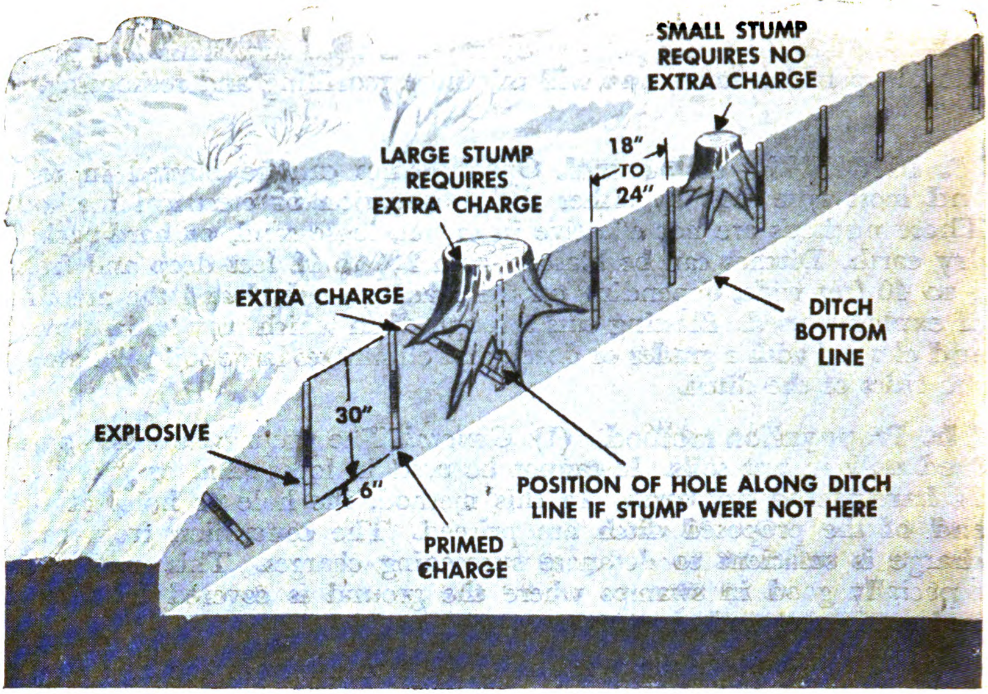
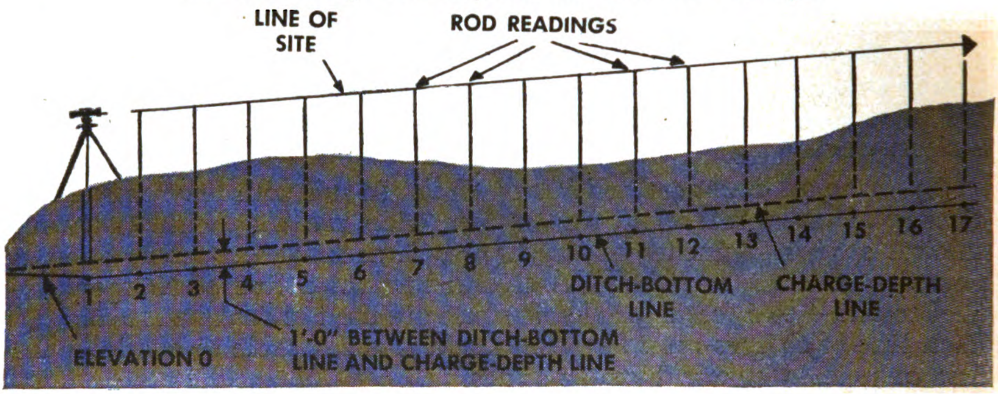


Figure 165. Line of holes loaded for a propagation ditch blast in wet soils. Note increased charge used in prime hole and under stumps.

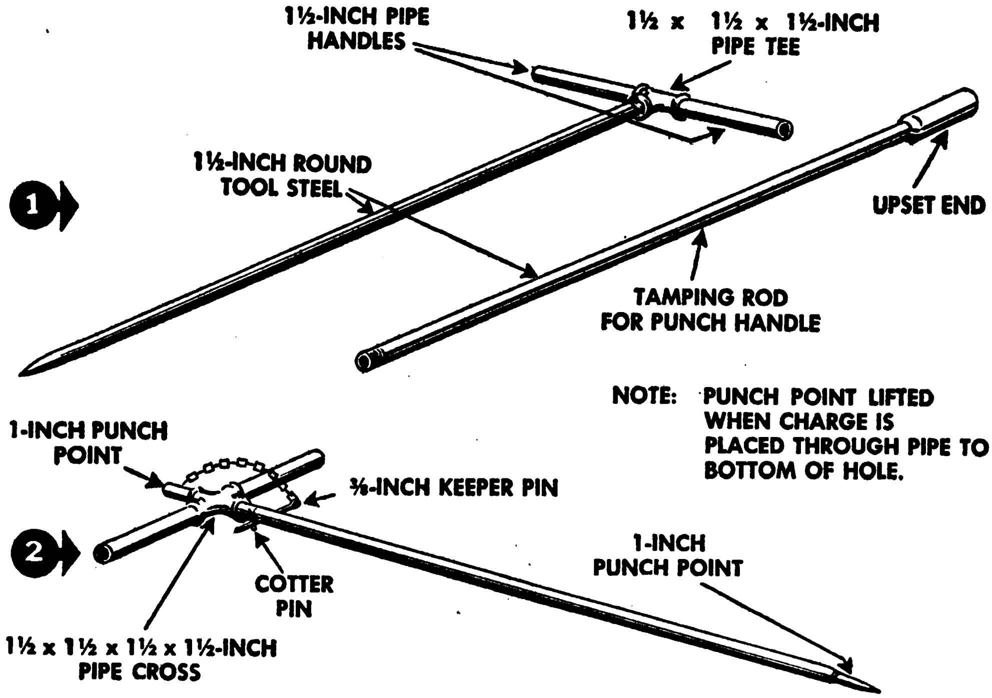


EXAMPLE CHARGE POINTS

(Elevations exaggerated for clarity)

CHARGE POINT	DITCH-BOTTOM-LINE ELEVATION (FEET)	CHARGE-DEPTH-LINE ELEVATION (FEET)	LINE-OF-SITE ELEVATION (FEET)	ROD READING (FEET)	GROUND ELEVATION ④-⑤=⑥ (FEET)	DEPTH OF HOLE ⑥-③=⑦ (FEET)
①	②	③	④	⑤	⑥	⑦
1	0	1	9	5.0	4.0	3.0
5	1	2	10	4.8	5.2	3.2
9	2	3	11	6.7	4.3	1.3
13	3	4	12	7.0	5.0	1.0
17	4	5	13	5.0	8.0	3.0

Figure 166. Using transit to set charge holes. Note rod readings for various ground elevations along the ditch line and the depth of hole required.



① *Sharp punch.*
② *Quicksand punch.*

Figure 167. Punches used to bore and set charge holes.

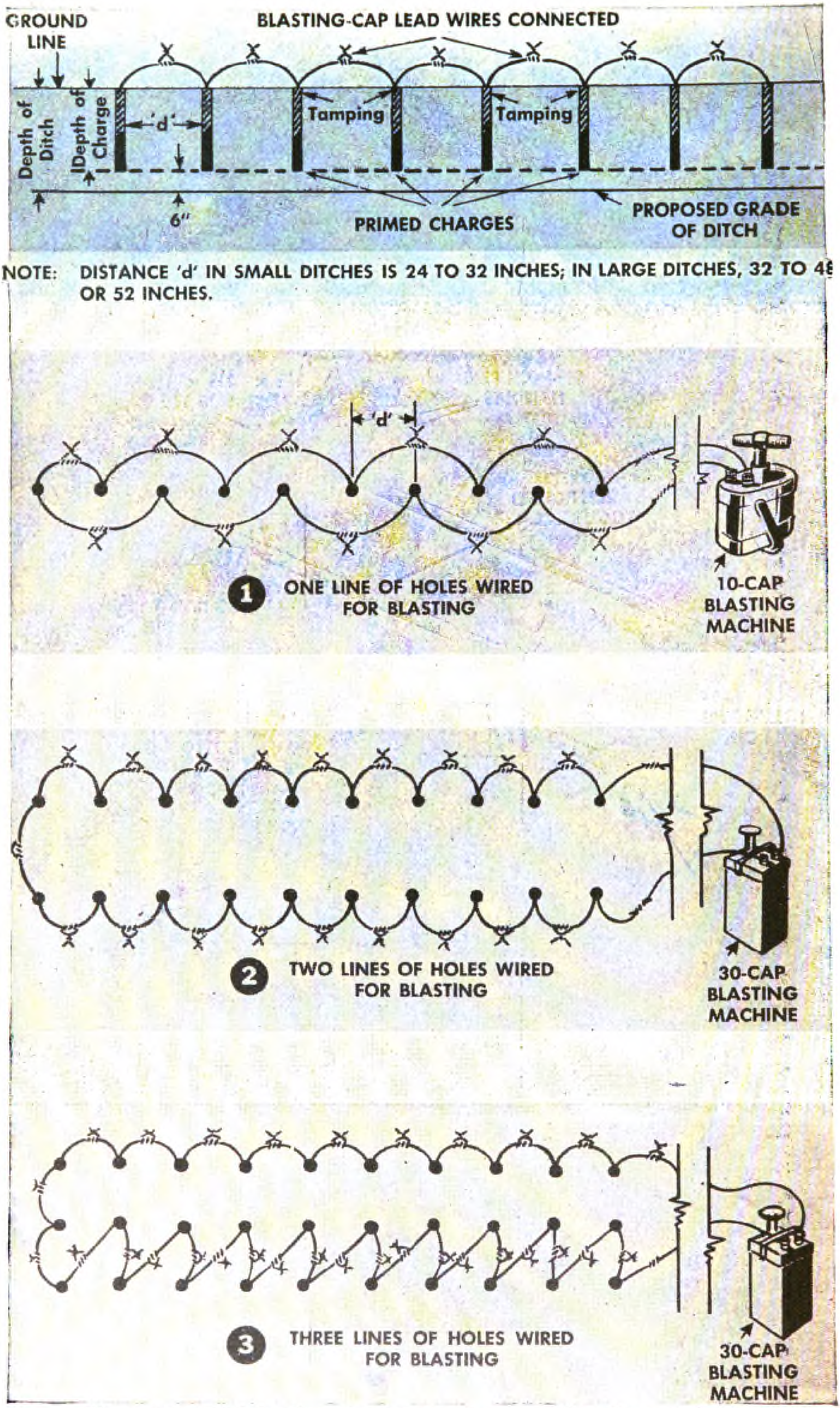
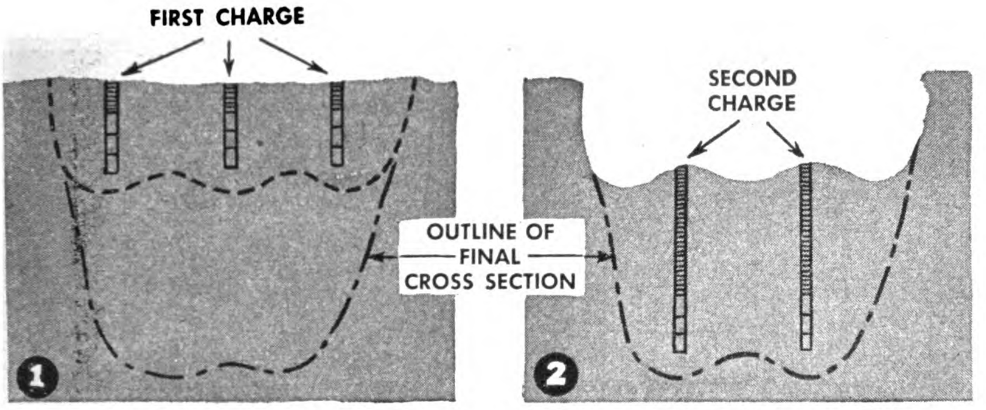


Figure 168. Ditch-loading plan for one, two, and three lines of charges.



① *First charge.*
② *Second charge.*

Figure 169. Method of loading deep, narrow ditch.

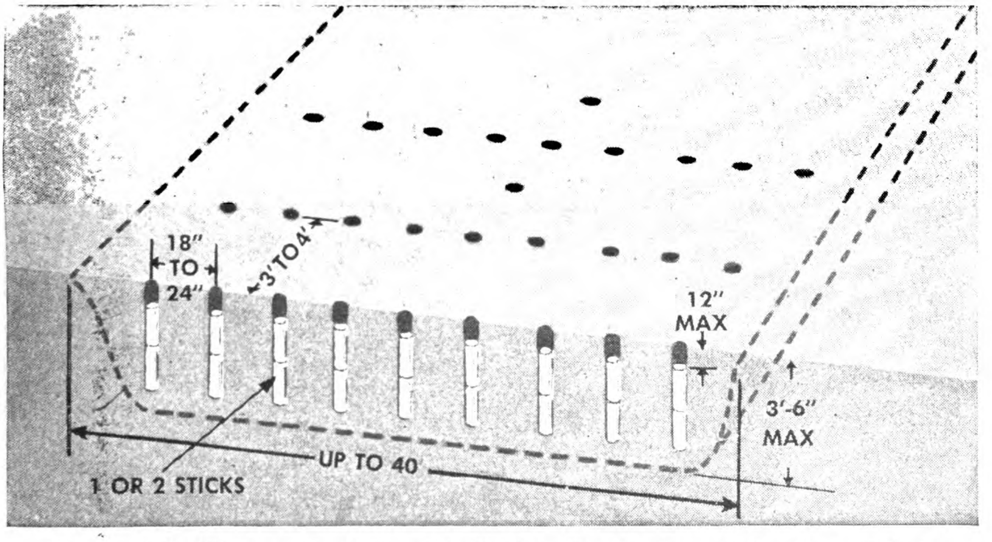


Figure 170. The cross-section method of loading to clean and widen ditches.

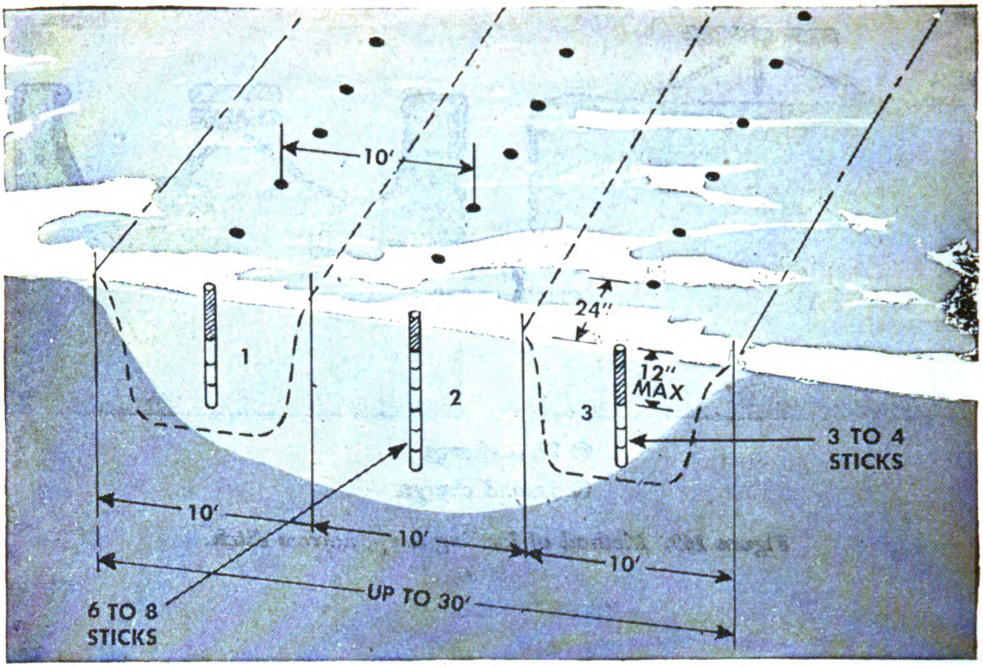


Figure 171. Relief method of loading for shallow ditches. Ditches one and three are blasted first to relieve the charge in two.

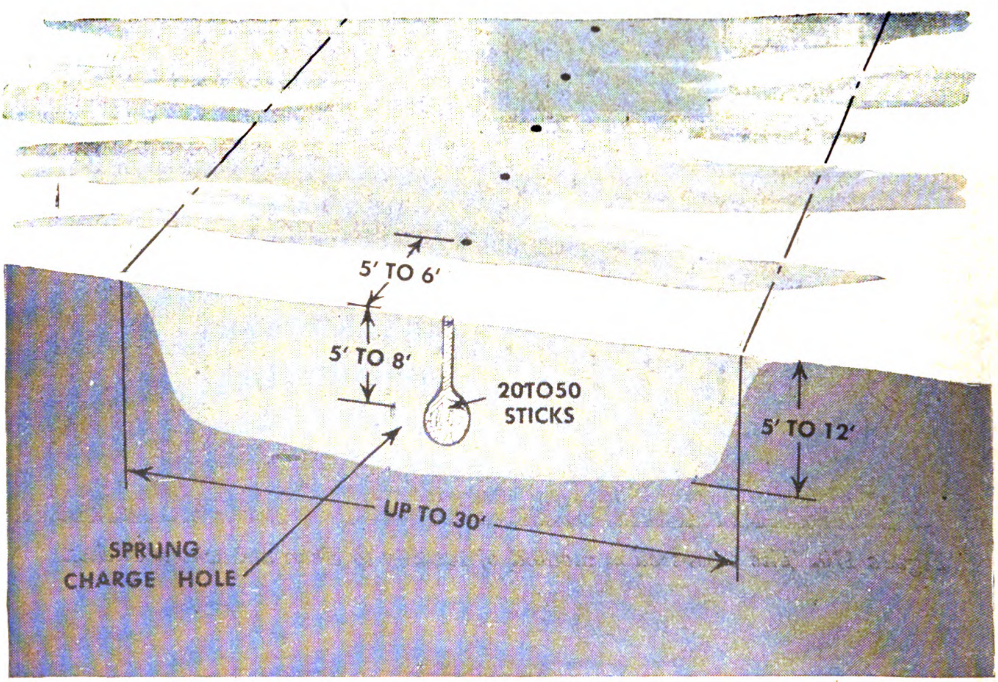
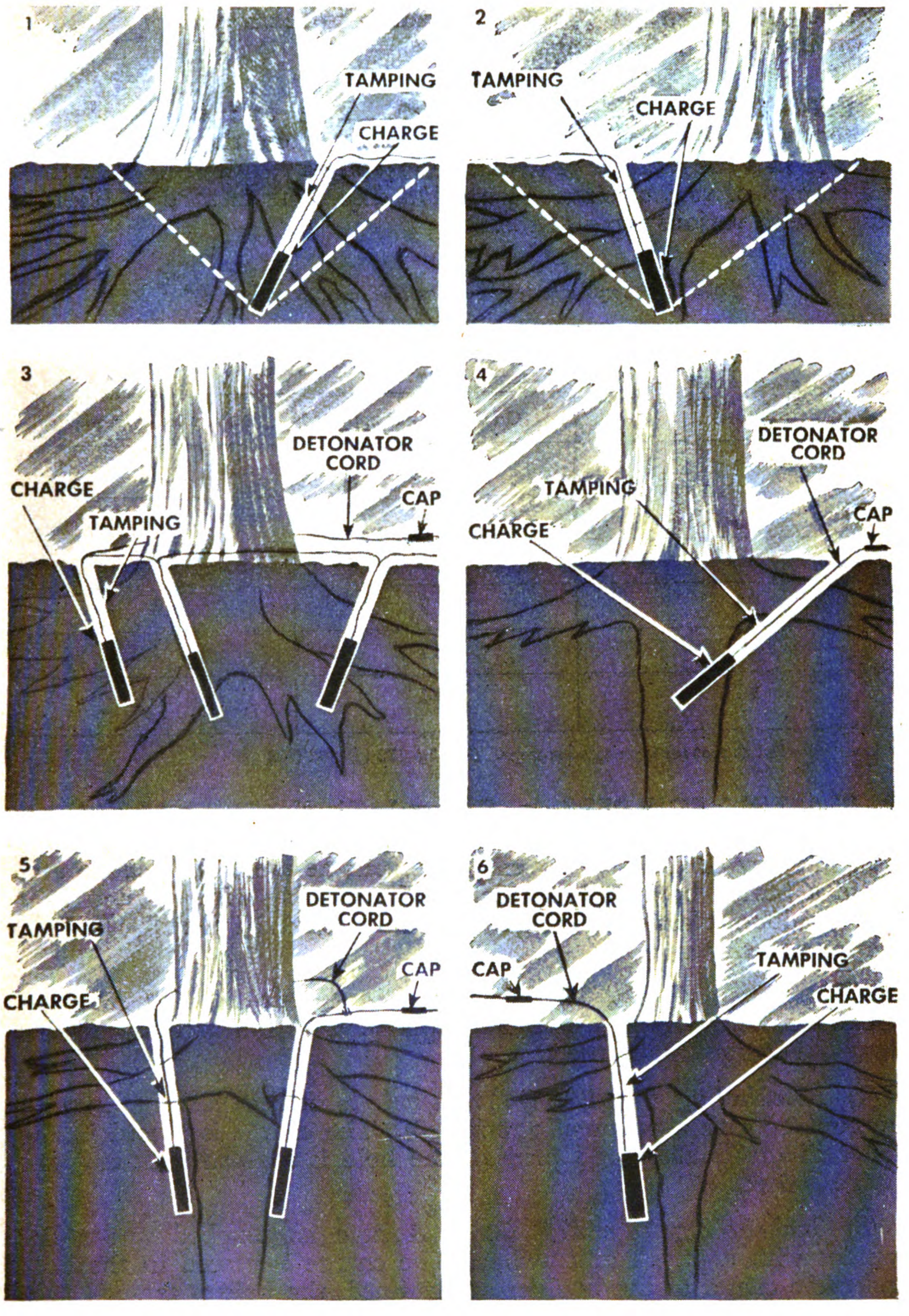


Figure 172. Post-hole method of loading for shallow ditches in mud.



① *Evenly rooted stump. Note that charge will blow out a right-angled cone.*
② *Large roots on one side of tree.*
③ *Large and heavy lateral brace roots. Charges are placed under strongest roots.*
④ *Large tap root bored to save explosive. This requires more time and labor.*
⑤ *Heavy tap root with strong brace roots equally distributed around the stump.*
⑥ *Small stump with large tap root.*

Figure 173. Stump blasting method for various tree sizes and root structures.

described in paragraph 78b (2). Loading methods and patterns are shown in figures 168 through 172.

79. BLASTING TREES AND STUMPS. Tree and stump blasting methods vary with the size and condition of tree and the root structure. Table L lists the number of dynamite cartridges required to blast trees and stumps of various sizes. Figure 173 shows the method of blasting stumps with various types of roots.

*Table L. Explosive required for tree or stump blasting**

Diameter of stump 1 foot above ground (inches)	Approximate number of 50 percent 1¼- by 8-inch dynamite cartridges	
	Green tree or stump	Dead tree or stump
8	2	1
12	3	2
18	5	3
24	7	4
30	11	5
36	14	6

* Charge loaded at root for tap-rooted stumps. (See fig. 173 (5) and (6).)

80. BLASTING BOULDERS. a. General. Blasting is a quick and easy way to remove and dispose of large boulders. Dynamite is commonly used, but any of the military explosives can be used. The shape and size of a buried boulder is determined by probing with pointed steel rod. Boulders blasted in congested areas should be heavily covered by rope and timber mats.

b. Blasting methods. There are three methods of placing charges—blockholing, snakeholing, and mudcapping. Any standard method of firing the charge can be used.

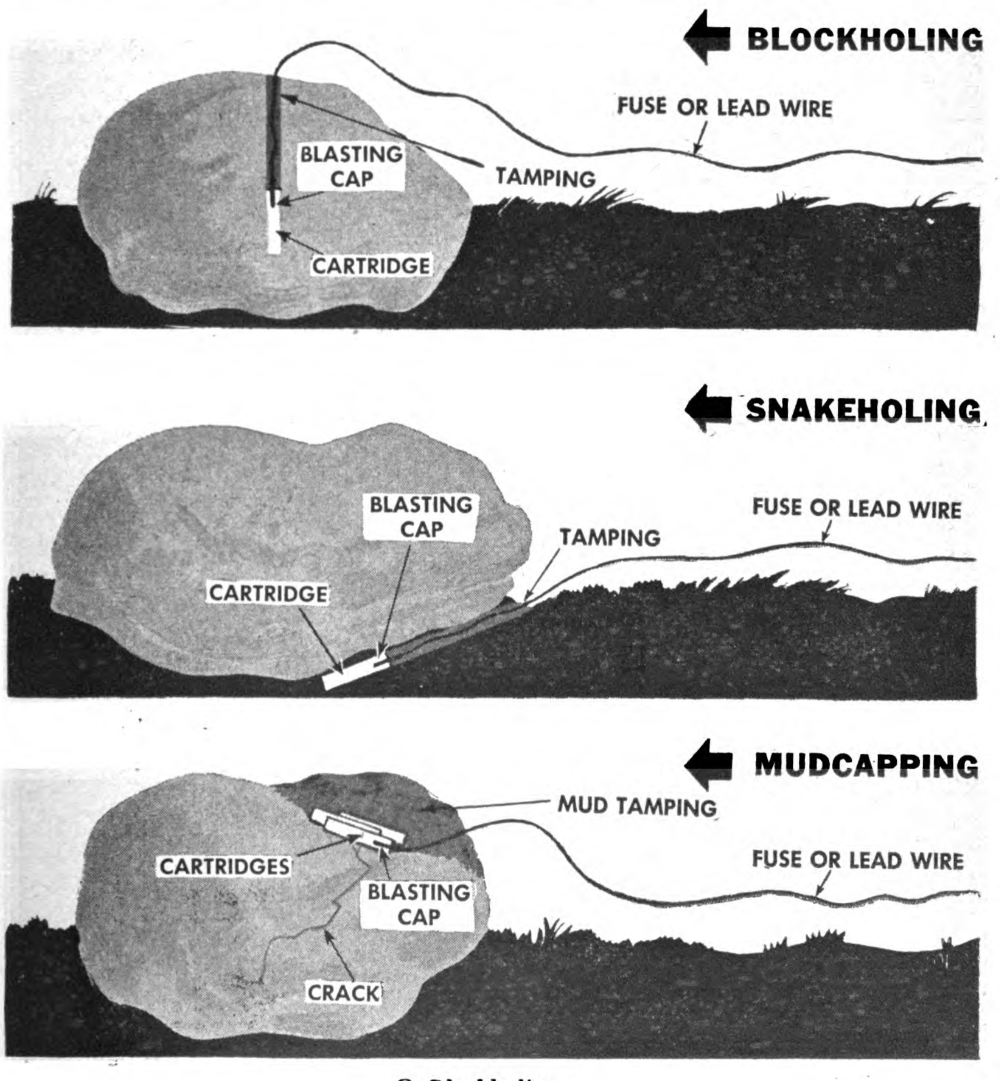
(1) *Blockholing* (fig. 174 (1)). A hole is drilled halfway through the boulder with a pneumatic rock drill. The charge is placed in the center of the boulder and primed, the hole is tamped full, and the charge is fired.

(2) *Snakeholing* (fig. 174 (2)). A hole is punched under the boulder with a punch or crowbar. The charge is placed in the hole under the center of the boulder and primed, the hole is tamped full, and the charge is fired. The charge will roll the boulder out of its hole or shatter it.

(3) *Mudcapping* (fig. 174 (3)). The charge is placed on top of the boulder and over a crack or in a depression if possible. The charge is covered with clay, mud, or sandbags full of sand and earth. *No rocks should be used in the tamping material.* The charge is fired and the boulder shattered.

c. Size of charge used. Listed below are the sizes of charges used on various size rocks for the methods listed above.

Boulder diameter (feet)	Dynamite cartridges		
	Blockholing	Snakeholing	Mudcapping
1½	¼	1	2
2	¼	1	3
3	½	1½	4
4	¾	4	7
5	1	6	12



① *Blockholing.*
② *Snakeholing.*
③ *Mudcapping.*
Figure 174. Blasting boulders.

Section IV. CONSTRUCTION DRAINAGE AND HYDRAULIC AIDS

81. NECESSITY FOR CONSTRUCTION DRAINAGE. Adequate drainage must be provided during the construction period for areas subject to stream overflow, or high ground-water table, particularly where rain or snowfall is heavy. The first construction work on any project should provide drainage for the work to follow. As new stages or work items are started, additional drainage facilities should be provided to insure that work will not be interrupted by accumulations of mud, water, and ice. At the end of each day's work and at any other time the project is shut down, steps should be taken to insure continuous drainage during the shutdown period. Failure to provide proper construction drainage delays and hampers all work and equipment, results in loss of moisture control in embankment filling and compaction, and leads to erosion of landing-strip surfaces, embankments, and cut slopes.

82. SUGGESTIONS FOR CONSTRUCTION DRAINAGE. When draining a construction site, attention should always be directed to—

a. Locating, opening, and cleaning out all natural drainage channels. Use power shovels, draglines, dozers, graders, or scrapers.

b. Opening and maintaining adequate intercepting ditches and dikes above cuts, storage areas, equipment parks, borrow pits, and quarries. Use graders, dozers, or scrapers for ditch excavation and dike construction.

c. Diverting from construction site all streams which might overflow into the construction area. Use power shovels, draglines, dozers, and scrapers or graders for channel excavation.

d. Installing adequate drainage outlets in borrow pits and quarries. Pumping installations will frequently be required.

e. Removing ruts and low spots and generally smoothing the surface of landing strips, roads, equipment parks, storage areas, and other traveled areas in the construction site. Use graders, drags, or scrapers.

f. Maintaining an adequate crown on all road and landing-strip surfaces with graders, drags, and scrapers. See FM 5–10 and TM 5–255 for specifications.

g. Maintaining all side slopes of cuts and fills. Slope must be correct for the particular soil type to prevent erosion which would fill side ditches with silt. Use graders or dozers.

h. Using well points and pumps to lower water tables which interfere with construction operations and cannot be lowered by open ditches.

i. Removing debris and silt from bridge and culvert openings to prevent their clogging during major flows. This is primarily a job for hand labor.

j. Providing pondage areas outside the construction site for drainage water which cannot be carried away by existing natural channels. The capacity of such ponds should be determined and balanced against the expected run-off during the construction period. Such pondage areas can usually be provided by constructing dikes with dozers, power shovels, draglines, or graders.

k. Providing sumps into which excess surface water can be diverted and later disposed of by pumping. This applies when terrain does not provide adequate natural drainage. Use draglines, power shovels, or dozers.

l. Filling holes left by the removal of trees and stumps. The dozer is the best machine for the purpose. The fill material should be thoroughly compacted, normally with a pneumatic tamper.

83. PIPE LINES. The quantity of water required for airdrome and road construction presents a difficult transportation problem, which can often be solved by pumping and piping systems if necessary equipment and material are available.

a. Distribution. Usual practice is to lay pipe down one side of a runway or road, inserting T-couplings every 200 or 300 feet. The T-couplings are closed with either plugs or short nipples and valves, water being delivered from the pipe through hoses.

b. Pressures. High pumping pressures are required if a large volume of water is to be pumped several miles. (See table LI.) Gravity flow may be used if the water source is above the distributing point. Three-inch pipe is recommended, although 2-inch pipe can be used.

*Table LI. Head required to deliver water at given rates through 1,000 feet of ordinary iron pipe. Head developed either by pump pressure or gravity**

Discharge quantity		Head in feet		
Gallons per minute	Gallons per 10-hour day	2-inch pipe	2½-inch pipe	3-inch pipe
20	12,000	18	6	3
30	18,000	38	13	6
40	24,000	66	22	9
50	30,000	99	33	14
60	36,000	138	46	19
70	42,000	183	62	26
80	48,000	236	79	33
90	54,000		97	40
100	60,000		120	50
110	66,000		144	60
120	72,000		167	70

*To obtain pressure in pounds per square inch, multiply figures given by 0.434.

84. PONDING. Sandy, gravelly soils may also be compacted by ponding. Small ridges or dikes forming a 25-foot square are constructed and the surface is flooded. The depth to which ponding is effective depends on the porosity of the material.

Caution: This method should not be used on plastic soils or when appreciable amounts of fine-grained soil binder material are present in the sand or gravel.

CHAPTER 5

CAPABILITIES AND USE OF LABOR

85. GENERAL. a. Purpose. The capabilities and use of labor in road or airdrome construction are discussed in this chapter.

b. Uses. Labor is used—

(1) To operate equipment.

(2) To work with hand tools in construction teams, thereby increasing equipment output.

(3) To perform by hand or with hand tools tasks which cannot be done with machines or for which machines are not available.

c. Types. There are three classifications of labor: troop labor, civilian labor, or prisoner-of-war labor.

d. Measures of work capacity. The ability of a unit to do work is measured by—

(1) Work output per man per hour.

(2) Man-hours per day normally available from the unit.

(3) Additional man-hours per day available from the unit in an emergency.

86. TROOP LABOR. a. Tables of organization. The amount, composition, and organization of troop labor in any unit is set forth in its table of organization. The officer in charge of a construction project must be familiar at all times with the tables of organization of units under his direction.

(1) The approved organization of each construction unit is the best for most jobs on which the unit will work; it should be adhered to except in special situations.

(2) The construction strength of a unit is the number of men actually available at the job after administrative and housekeeping personnel have been assigned. Table LII tabulates this break-down for various engineer troop organizations.

b. Use of specialists. Each unit is provided with men specially trained to handle every type of technical duty normally encountered by the unit. Full use should be made of these specialists.

87. CIVILIAN LABOR. The demands for construction within a theater of operations normally exceed the capacity of available engineer troops. Whenever possible, this deficiency is made up by using native civilian labor. Frequently the officer in charge is empowered to solicit, classify, and employ local native civilians. They are employed and paid in accordance with theater policy and directives.

a. Employing labor. Local security, prevention of pilferage and sabotage, and work efficiency demand careful selection of civilian personnel. The officer in charge carefully selects a labor superintendent and together they contact local leaders to plan procurement procedures. The labor superintendent should be a local labor leader, tribal or

Table LII. Construction strength

	Engineer general service regt T/O 5–21, 1 April 1942; C 1, 1 Aug 42; C 2, 29 Aug 1942; Cir 261 WD, 20 Oct 1943; Cir 287 WD, 8 Nov 1943				Engineer combat bn T/O & E 5–15 13 Mar 1944			Engineer construction gp T/O & E 5–72 and 5–75, 23 Dec 1943					Engineer aviation bn T/O & E 5–415, 15 May 1944			Airborne engineer aviation bn T/O 5–455, 4 May 1943		
	Letter Co	Bn	Hq and H&S Co	Regt	Letter Co	Hq and H&S Co	Bn	Letter Co	Bn hq and H&S Co	Bn	Gp hq and H&S Co	Total group	Letter Co	Hq and H&S Co	Bn	Letter Co	Hq and H&S Co	Bn
1 T/O STRENGTH																		
Commissioned officers	5	17	13	53	5	12	29	5	11	29	11	98	5	14	29	5	9	24
Warrant officers	0	0	2	2	0	3	3	0	2	2	2	8	–	–	–	–	1	1
Enlisted men	176	533	134	1,239	170	109	619	220	244	913	81	2,820	178	226	760	124	116	488
TOTAL	181	550	149	1,294	175	124	651	225	257	944	94	2,926	183	240	789	129	126	513
2 ADMINISTRATIVE PERSONNEL.	33	106	83	340	22	63	131	28	84	168	69	573	25	64	139	20	58	118
3 CONSTRUCTION PERSONNEL.	148	444	66	954	153	61	520	197	173	776	25	2,353	158	176	650	109	68	395
4 REDUCTION IN CONSTRUCTION PERSONNEL																		
Sickness:																		
Hospital	2	6	2	14	2	1.5	7.5	2	2	8	2	26	2	2	8	1.5	1.0	5.5
Infirmary	1	3	1	7	1	0.75	3.75	2	2	8	2	26	1	2	5	0.75	0.50	2.75
Quarters	1	3	1	7	1	0.75	3.75	1	1	4	1	13	1	1	4	0.75	0.50	2.75
Special duty:																		
Mess	4	12	4	28	4	3	15	5	5	20	5	65	4	5	17	3	3	12
Company latrine	1	3	1	7	1	1	4	1	1	4	1	13	1	1	4	1	1	4
Company charge of quarters.	1	3	1	7	1	1	4	1	1	4	1	13	1	1	4	1	1	4
Guard	4	12	3	27	5	3	18	7	7	28	6	90	4	7	19	3	3	12
Camp	3	9	3	21	3	2	11	4	4	16	4	52	3	4	13	2	2	8
Special	3	9	3	21	3	2	11	3	3	12	3	39	3	3	12	2	2	8
TOTAL	20	60	19	139	21	15	78	26	26	104	25	337	20	26	86	15	14	59
5 CONSTRUCTION STRENGTH.	128	384	47	815	132	46	442	171	147	672	0	2,016	138	150	564	94	54	336

village chieftain, or other person of locally recognized authority. The hiring of undesirable elements or sections of the labor market can be avoided by working with local leaders.

(1) Local existing wage scales are used.

(2) Work supervisors, foremen, and squad bosses, classified and hired beforehand, are used to recruit labor.

(3) Labor is carefully screened to separate skilled individuals such as masons, carpenters, and concrete finishers. These individuals are assigned to duties using their special abilities.

(4) Civilian labor is divided into separate groups wherever local custom and religious affiliation demand it.

(5) If practicable, a clerical administrative section is hired so the entire civilian labor organization becomes a balanced work unit requiring a minimum of military supervision.

b. Assignment. The maximum number of civilians that can effectively be placed under supervision of various engineer units is shown below. In general, it is assumed that nine laborers per squad of a general service regiment or equivalent unit is the most practical number. The numbers shown may be used for planning purposes although specific cases may warrant considerable variations. The civilian component of each lettered company is referred to as a "civilian construction group"; the unit assigned to headquarters and headquarters and service company is referred to as "civilian headquarters group." It is estimated that 10 percent of the civilians assigned to lettered companies can be employed as a civilian headquarters group. Maximum numbers for effective employment are:

(1) *Engineer general service regiment.*

Civilians per squad	9
Civilians per civilian construction group (company)	81
Six civilian construction groups (two battalions)	486
Civilians per civilian headquarters group	49
Total civilians	535

(2) *Engineer combat battalion.*

Civilians per squad	9
Civilians per civilian construction group (company)	81
Total of three groups (battalion)	243
Civilians per civilian headquarters group	24
Total civilians	267

c. Construction strength. Normal weekly reduction of strength in civilian construction personnel is estimated below. These figures should be adjusted by experience in a given area. Percentages given are of the number of civilians doing construction work, excluding administrative personnel.

(1) Health reduction 14 percent (1 day per week per man).

(2) Absentees 7 percent, caused by temperament, misunderstanding, variation in language and customs, religious obligations, and adjustment to conditions (½ day per week per man).

(3) Time off duty 14 percent (1 day of rest per week per man).

d. Supervision. Civilian laborers are organized into crews under civilian foreman and subforemen. A specially designated officer or noncommissioned officer, such as the platoon sergeant of a platoon to which native civilian labor crew is attached, issues instructions to the foremen and subforemen on the nature of the task and the results expected, and makes recommendations on how it can best be done. The designated officer or noncommissioned officer inspects the work frequently to see that desired results are being achieved and makes any criticisms to the foreman. He does not interfere with the work or supervise the individual laborers.

e. Discipline. Discipline is just, firm, and rapid, but is resorted to only when there is no alternative. When it is necessary to discipline a civilian employee, he should be brought alone before the officer in charge with all his superiors and a good interpreter present. The inquiry is conducted in his language and the degree and extent of fault is fairly determined. Firm reprimand or a few days enforced lay-off solves most difficulties. Reduction either in pay or in grade and pay may be imposed. Serious cases may require discharge with pay for labor performed, or civil action by local courts, or both. Fines, capital punishment, or cruel or tyrannical penalties cannot be imposed.

88. PRISONER-OF-WAR LABOR. a. Procurement. Prisoners of war are requested by grade from the local provost marshal to form a labor unit similar in organization to the engineer unit to which they are attached. Mess, kitchen police, supply, clerical, and fatigue personnel are included in the request to form a balanced labor unit. Prisoner commissioned personnel, other than captured medical officers, are seldom used.

b. Handling prisoners of war. Attachment of prisoners of war to a construction unit normally requires the establishment of a prisoner-of-war camp or compounded with complete administrative functions. Regulations governing prisoners of war are published in a series of War Department Prisoner of War Circulars. Military discipline and courtesy are firmly enforced. Prisoners are subject to the laws, regulations, and orders in force in the Army of the United States, including the Articles of War. Regulations affecting the conduct and activities of prisoners are posted conspicuously in their native language. Prisoners are treated humanely at all times and are protected against violence, insults, and curiosity. Measures of reprisal are prohibited and prisoners retain the right to have their person and their honor respected.

c. Use of prisoners. Prisoners may be employed only on projects permitted by the Geneva Convention. War Department directives further restrict prisoner-of-war employment. Tools remain in possession of prisoners only during work hours.

d. Supervision. Prisoners of war are supervised by their own noncommissioned officers, who receive instructions on the nature of the task, the results expected, and how the task shall be performed, from the officer in charge of the project or a designated representative. Work output of prisoner-of-war labor is normally much lower than that of troop labor because of the prisoner's low morale and their lack of familiarity with our methods and tools.

89. WORK OUTPUT PER MAN-HOUR. The work accomplished by one man in 1 hour is the basis for estimating the work output of labor. Tables of average work output per man-hour on various tasks are shown in FM 5–10, 5–35, and TM 5–255. These should be supplemented by records maintained by each unit. The work one man will produce in an hour varies widely and depends on the following factors.

a. Morale. The condition of an individual or group with regard to courage, confidence, and enthusiasm in the performance of duty is morale. If morale is to be high—

(1) The individual must believe that the work is essential and worthwhile, and he must understand its relationship to the over-all effort. This is particularly true of troop labor.

(2) The individual must feel that he is doing his fair share; that is, that others are not idling while he is working, and that he is not kept idle when there is essential work to do.

(3) The individual must feel that his living conditions are the best possible under existing conditions. Poor food is a major and immediate cause of discontent. Time and facilities must be available to attend to personal hygiene and cleanliness.

(4) Esprit de corps must be developed. A healthy spirit of competition between units will greatly increase the work output.

(5) Mail must be delivered as often as possible.

(6) Individual problems and grievances must receive fair and prompt attention.

b. Physical condition. The strength, stamina, and general health of an individual affects his work output, which drops off rapidly if he becomes tired or ill. Physical condition must be given special consideration in estimating work output of native civilian laborers, since they are frequently poorly fed and diseased.

c. Working conditions. Climate, terrain, safety precautions, and enemy interference determine working conditions.

(1) Output per man-hour decreases during intense heat, severe cold, or continued rain or snow.

(2) Men cannot work at their normal rate when hampered by muddy or frozen ground, dense or tangled vegetation, or when annoyed by insects.

(3) If the men believe that construction methods or equipment are unsafe, they will not give maximum work output.

(4) Enemy interference does not necessarily tend to decrease work output per man-hour. If the men feel that an adequate warning and outpost system is employed, they may even increase their work output to finish the job as quickly as possible.

d. State of training. If men are properly trained when a job begins, their initial work output will be greater than the output of untrained personnel. In either case, work output will increase as the job progresses. Native laborers will produce more when assigned to tasks with which their native experience has made them familiar.

90. NORMAL MAN-HOURS PER DAY. The number of man-hours which normally can be worked per day depends on:

a. The *construction strength* of the unit.

b. The *length of work day,* which is determined by the hours of day-

light (table LIII) and the availability of lighting equipment for night work.

Table LIII. Hours of daylight[1]

Latitude north[2]	Month											
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
0°	12	12	12	12	12	12	12	12	12	12	12	12
10°	12	12	12	12	13	13	13	12	12	12	12	12
20°	11	12	12	13	13	13	13	13	12	12	11	11
30°	10	11	12	13	14	14	14	13	12	11	11	10
40°	10	11	12	13	14	15	15	14	12	11	10	9
50°	9	10	12	14	15	16	16	14	12	11	9	8
60°	7	9	12	15	17	19	18	16	12	10	8	6
70°	0	7	12	16	23	24	24	18	12	9	4	0
80°	0	0	12	24	24	24	24	24	12	5	0	0

[1] Time between sunrise and sunset. Approximately 30 minutes twilight is available before sunrise and after sunset.
[2] For latitude south, subtract figure given from 24.

c. The *number of shifts* either one or two, depending on the size of the unit, the length of the day, and the available tools and equipment.

91. EMERGENCY MAN-HOURS. In an emergency the work output of engineer troops can be increased as follows:

a. During full moon. Three days before and after the full moon, construction activities can be carried on in the open, at night, without lights. Based on an additional working time of 3 hours per day and a reduction factor of 45 percent for overcast skies and reduced efficiency, additional man-hours that can be obtained for each full-moon period are shown in table LIV. Dates of occurrence of full-moon phases are shown in table LV.

Table LIV. Emergency time available between sunset and sunrise during full moon

Component	Organization									
	Gen. serv. regt.		Combat bn.		Cons. bn.		Engr. avn. bn.		AB Engr. avn. bn.	
	Cons. strength	Man-hours	Cons. strength	Man-hours	Cons. strength	Man-hours	Cons. strength	Man-hours	Cons. strength	Man-hours
1 man	1	10	1	10	1	10	1	10	1	10
Regt	954	9,540	--	--	--	--	--	--	--	--
Bn	444	4,440	442	4,420	672	6,720	574	5,740	336	3,360
Co	148	1,480	132	1,320	171	1,710	138	1,380	94	940

*Table LV. Date and time of full moon**

Month	1944		1945		1946		1947		1948	
	Date	Time	Date	Time	Date	Time	Date	Time	Date	Time
January			28	0641	17	1446	7	0447	26	0711
February			27	0007	16	0428	5	1550	24	1716
March			28	1744	17	1911	6	0315	25	0310
April			27	1033	16	1047	5	1528	23	1328
May			27	0149	16	0252	5	0453	23	0037
June			25	1508	14	1842	3	1927	21	1254
July			25	0225	14	0922	3	1038	21	0231
August			23	1203	12	2226	2 31	0150 1634	19	1732
September	2	2021	21	2046	11	0959	30	0641	18	0943
October	2 31	0422 1335	21	0532	10	2040	29	2007	18	0223
November	30	0052	19	1513	9	0710	28	0845	16	1831
December	29	1438	19	0217	8	1752	27	2027	16	0911

* All times Greenwich civil time.

b. Using administrative personnel. Approximately 60 percent of the personnel classified as "administrative" can be used for short periods on construction duty. The resulting increase in construction strength is shown in table LVI. An efficiency reduction of 10 percent is made to cover lack of skill of administrative personnel in construction work.

Table LVI. Emergency use of administrative personnel

Component	Organization									
	General service regt.		Combat bn.		Cons. bn.		Engr. avn. bn.		AB Engr. avn. bn.	
	Increased construction strength	Percent increase	Increased construction strength	Percent increase	Increased construction strength	Percent increase	Increased construction strength	Percent increase	Increased construction strength	Percent increase
Regt.	985	21	---	--	---	--	---	--	---	--
Bn.	437	14	507	15	762	12	644	12	395	17
Co.	144	12	144	11	186	9	150	9	104	11

CHAPTER 6

PLANNING CONSTRUCTION OF IMPROVED ROADS AND AIRDROMES

Section I. BASIC CONSIDERATIONS

92. SCOPE. This chapter tells how to manage a road or airdrome construction project.

93. PHASES OF MANAGEMENT. The two phases in the successful management of a construction job are first, planning and scheduling, and second, keeping work on schedule by close supervision.

a. Scheduling. (1) *Definition.* Scheduling is the process of working out a detailed time plan which coordinates all construction operations and indicates how available equipment and labor will be used to complete the job in the shortest possible time. A schedule is usually in graph form; see section II for details on preparation.

(2) *Use.* The schedule serves as a control chart when assigning equipment and labor and assembling materials during construction. It is also used as a progress chart to guide supervision.

b. Supervision. Supervision is the control, coordination, and adjustment of construction schedules. It involves careful personal inspection, and review and analysis of schedules and progress reports, work output records, and equipment records. See section III for detail methods and check lists to be used in inspection, and for information on how to use various types of progress and work output records.

94. DEFINITIONS. The following terms are used in discussing scheduling and supervision:

a. *Stage construction* is the procedure followed when a project is completed either by units or by levels of improvement. Stage construction permits early use of items of high priority such as taxiways for an airdrome, or of the unimproved project as a whole, such as a compacted road subgrade.

b. *Engineering designs* for a project consist of lay-outs, profiles, cross sections, and mass diagrams. See FM 5–10, TM 5–230, 5–235, and 5–255 for detailed information on the preparation of these designs.

c. *Work items* are specific tasks for which work output of men and equipment is known or can be estimated. Some work items, like compaction, are performed in a single basic operation; others, like excavation which may include digging, loading, hauling, and dumping, require several basic operations.

d. *Quantity* is the number of units, such as cubic yards of excavation or square yards of surface treatment, used to measure a work item.

e. *Quantity survey* is the process of determining the quantities for all work items in a project. The quantities are taken from engineering designs or measured by field surveys.

f. *Resources* include equipment, personnel, materials, and construction facilities either on hand or available.

g. *Construction facilities* include buildings, piers, trails, roads, airdromes, water points, lighting, equipment parks, dispersal areas, and similar facilities required during construction.

h. *Construction teams* are made up of men and equipment organized to obtain maximum work output on a given task. An example is the earthwork team consisting of the power shovel as the key tool, with dump trucks to haul and dump, dozers or graders to spread, and rollers to compact.

i. *Key equipment* is the piece of equipment about which a construction team is organized. It controls the output of the team provided sufficient auxiliary equipment is available.

j. *Controlling work items* are work items which, because of the volume and character of work involved, control the scheduling and assignment of equipment and labor. Examples of controlling work items are clearing and grubbing in jungle construction, or excavation and fill in mountain construction.

k. *Sequence* is the order in which operations must begin. Some operations cannot begin until other operations have been completed. For example, excavation must follow clearing and grubbing. Succeeding operations usually can begin as soon as preceding operations are complete on sufficient area to avoid interference.

l. *Advance planning and preparation* is that work which must be either partially or totally complete before actual construction operations can begin.

Section II. SCHEDULING

95. INTRODUCTION. The construction-operations schedule showing the sequence of operations and the time allotted each work item and task is the master schedule in all construction projects. The detail included in the schedule and the need for supplemental equipment, labor, and material schedules depend on the size of the project. A large project including several stages, many work items, and a large amount of equipment, labor, and materials requires all these supplemental schedules and considerable detail in each. A small project including only a few work items and limited equipment, labor, and materials may require only a brief construction-operations schedule with attached notes on equipment, labor, and material requirements.

96. STEPS IN SCHEDULING. In normal sequence the essential steps in preparing the construction-operations schedule are:

a. General study of job, including forecast of working conditions. (See par. 97.)

b. Inventory of available resources. (See par. 98.)

c. Quantity survey. (See par. 99.)

d. Working out detailed schedule of operations. (See par. 100.)

e. Summarizing detailed schedule of operations in a master construction-operations schedule and in supplementary labor, equipment, and material schedules. (See par. 101.)

97. GENERAL STUDY. a. Basic considerations. When the officer in charge begins scheduling the job, he must consider the following:

(1) The *theater construction policies* issued by theater headquarters and establishing uniform construction practice as well as uniform and economic procedures for use of vital engineer construction materials.

(2) The *job directive* issued in either oral or written form by higher headquarters. It is usually accompanied by the approved reconnaissance report. The directive contains the following information:

(*a*) *Requirements* of the project, normally including:

1. Tactical. The stages of construction of the project as dictated by tactical needs.

2. Technical. Technical specifications to be met in each stage. No more work than necessary to meet these specifications is to be undertaken.

(*b*) *Engineering designs* for the project. These are usually transmitted for rear-area installations of considerable size. For more forward installations, responsibility for the preparation of designs usually rests with the officer in charge of construction, who is guided by the sketch plans accompanying the approved site-reconnaissance report.

b. Reconnaissance. Personal reconnaissance of the construction site is necessary to determine topography, drainage, soil, and geology, vegetation, local material, and existing construction facilities.

c. Forecast of working conditions. Estimates are made of the conditions under which work will be carried on.

(1) *Weather.* Abnormal weather conditions such as continuous rain, severe storms, or below-freezing temperatures can seriously disrupt construction plans. Every attempt should be made to anticipate and plan for such occurrences. (See fig. 175.)

Figure 175. Water and mud greatly reduce the work output of these 8-cubic-yard tractor-drawn scrapers. Proper preliminary drainage and continuous maintenance on this airdrome would have eliminated the mud and water.

(2) *Enemy action.* Enemy action may necessitate changes in mission, in requirements, or in construction procedure. If attack either by ground, air, or artillery is anticipated, certain precautions should be taken. These include camouflage and dispersal of equipment and installations, and selection of alternate sites for construction facilities. (See ch. 1.)

(3) *Night operation.* If night operation is necessary to speed completion of a project, schedules must be adjusted to allow for the lower hourly output in darkness hours and plans must be made to provide adequate lighting.

98. INVENTORY OF RESOURCES. The officer in charge inventories the equipment, labor, materials, and construction facilities on hand or known to be immediately available. Resources immediately available can be obtained on loan or requisition from a depot, equipment company, dump truck company, or other unit.

a. Equipment. A table is used to list all available equipment showing the condition of each item and the date it will be available. Table LVII is an example of such a list.

Table LVII. List of available equipment

Piece	Condition	Date available	Number available
Tractors (D8)	Good	6 June	10
Tractors (TD18)	Good	6 June	9
Tractors (D4)	Poor*	6 June	4
Scrapers, road, towed (8-cu yd)	Good	6 June	5
Scrapers, road, towed (12-cu yd)	Good	6 June	5
Rooters, road, towed	Good	6 June	2
Roller, sheep's-foot, 2 drum-in-line	Good	6 June	2
Roller, 10-ton, 3-smooth wheel	Good	6 June	1
Roller, 6- to 8-ton, 2-axle, tandem	Good	6 June	1
Grader, motor, patrol	2—Good 1—Under repair	6 June 15 June	3
Power shovel, ¾-cu yd, truck-mounted	Good	6 June	1
Power shovel, ¾-cu yd, crawler-mounted	Good	6 June	1
Dump trucks (2½-ton)	Good	6 June	15

* In poor mechanical condition with repair parts unavailable.

b. Labor. Construction strength of the unit plus attachments of civilian personnel is determined in accord with the methods and principles explained in chapter 5. Drivers and crews of equipment and specialists required for technical duty are subtracted from the con-

struction strength to obtain the actual number of men available for hand labor.

c. Materials. (1) Depot stock piles and local civilian stocks are checked to see if the necessary amounts of cement, bitumen, lumber, and other manufactured materials are available.

(2) The possibility of securing timbers for bridges and culverts from material which must be cleared from the construction site is checked during reconnaissance.

(3) The adequacy, availability, and location of quarries and gravel and soil pits are checked by reconnaissance. The output of the quarry or pit should be sufficient to meet daily requirements and at the same time maintain stock pile in case of equipment break-down.

d. Facilities. (1) Existing roads and trails are reconnoitered as possible haul and access roads. Notes are also made of the maintenance required to keep these roads in condition for most efficient use.

(2) Suitable dump areas for waste material from excavation and clearing are located. They should be located where haul distance is at a minimum and construction and operation activities are least interfered with. They should be available by the time excavation or clearing begins.

(3) Sources of water suitable for construction water supply are located and their capacity indicated. Water is needed for washing aggregate, mixing concrete, and sprinkling fill or other material during compaction. It may be obtained from streams, springs, reservoirs, lakes, or existing pipe lines. If a great deal of water is required as in sprinkling fill and base-course material for compaction, it may be advisable to construct a pipe line directly to the site to avoid tying up an excessive amount of hauling equipment.

(4) Areas suitable for equipment parks, dispersal areas, and repair sections are noted. They should be convenient to the work site.

99. QUANTITY SURVEY. Quantities taken from engineering designs or field surveys are expressed in units suitable to each work item. Table LVIII gives standard units for the more common work items.

100. WORKING OUT DETAIL SCHEDULE. a. Scope. To obtain the best plan for the most rapid completion of the project with available resources, the entire job must be thought through, step by step, as equipment and labor assignments are made and the construction-operations schedule is drawn up. In thinking the job through, the officer in charge must—

(1) Anticipate all work items involved. This is done in preparing the quantity survey. (See par. 99.)

(2) Forecast special situations and unusual conditions which may arise during the construction period. This is part of the general study. (See par. 97c.)

(3) Foresee the necessity for construction facilities and aids. This is part of the inventory of resources. (See par. 98d.)

(4) Tentatively decide how to do each task.

(5) Schedule and assign operations, labor, equipment, construction teams, and materials.

Table LVIII. Standard units of measure for work item quantities

Work item	Unit of measure	Remarks
Clearing and grubbing		
Trees, stumps, and boulders	acre	Actual area, does not include bare spots.
	each	When removal requires special methods or equipment.
Stripping		
Light stripping	acre	
Heavy stripping	cu yd	Average haul distance
Hauling	feet	
Ditching and diking		
Deep	cu yd	If nonuniform or involves large quantities.
Shallow	lin ft	If uniform or involves small quantities.
Water supply		
Pumping	gpm	The pumping head or difference in elevation is expressed in feet.
	gph	
Earthwork		
Excavation	cu yd	Measured in place, before removal.
Structure excavation	cu yd	Measured in place, before removal.
Hauling	feet	Center of mass in cut to center of mass in fill.
Spreading and compacting	cu yd	Spread and compacted in layers of specified thickness.
Subgrade		
Scarifying and shaping	sq yd	
Stabilizing, pulverizing, mixing, or compacting	sq yd	
Aggregates		
Quarrying, crushing, screening, or washing	tons	Used for plant output.
	cu yd	Loose measurement in stock pile.
Bituminous surfaces		
Surface treatment	sq yd	
Penetration	sq yd	
Mixed-in-place	sq yd	If subgrade material is used for aggregate.
	cu yd	If aggregate is imported and spread on surface.
Plant-mixed	cu yd	Measured in place after compaction.
	tons	If scales are available at plant.
Portland-cement concrete	cu yd	Estimate of volume actually to be placed. Quantities of gravel, sand, and cement are estimated from table XL, FM 5–10, and paragraph 129, FM 5–35.

b. Guiding principles. In planning the work and making out the schedules, the officer in charge should keep certain guiding principles in mind and plan to—

(1) Complete the project by stages in accordance with the dates established by directive.

(2) Have construction aids and facilities ready in time to fulfill their function. Make full use of existing facilities.

(3) Start work items and tasks in their proper sequence.

(4) Begin work on controlling work items as early as possible. Assignment of labor, equipment, and construction teams to such items has first priority.

(5) Assign equipment, labor, and construction teams to only one task at a time. So far as possible allow no teams to be idle between tasks.

(6) Have materials available by the time work on work items for which they are required begins. This requires that—

(*a*) Crushing, screening, and washing plants be in operation in time to assure adequate stock piles of material when work on base course or surfacing begins. The output of the plant should be sufficient to meet daily requirements and to maintain moderate stock piles in case of equipment break-downs.

(*b*) Concrete and bituminous mixing plants be in operation before paving begins. The output of these key plants determines the amount of mixed concrete or bituminous materials available hourly. Haul distances for cement, bitumen, aggregate, water, and mixed materials must be as short as possible. Enough hauling equipment must be available to keep the plant output moving over the haul distance.

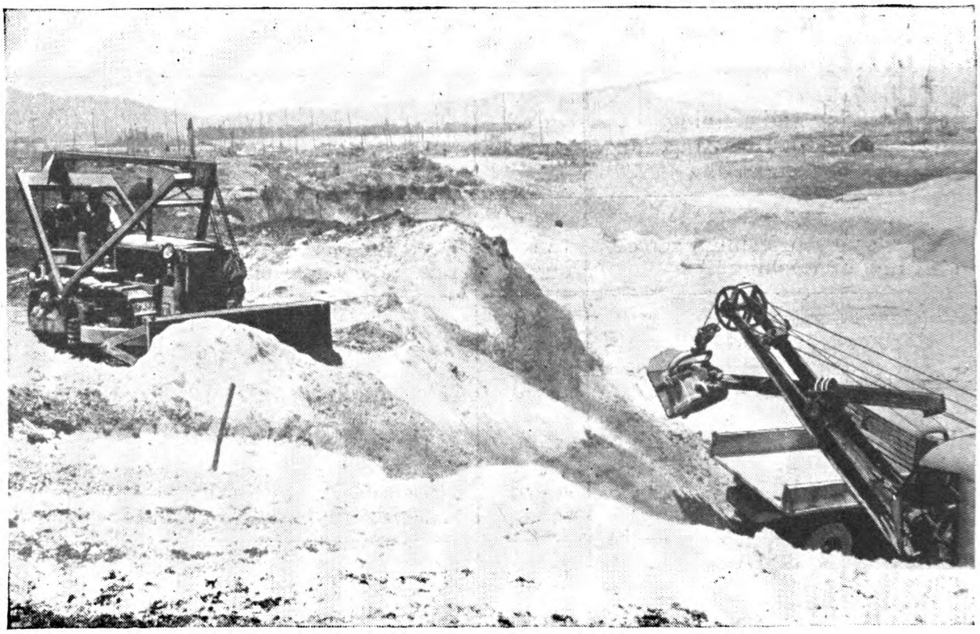


Figure 176. Coral being excavated from a deep face by a ½-cubic yard power shovel. Shovel is making short, rapid swings to the dump truck while tractor-mounted angledozer is pushing top layer of material down to the shovel to prevent undercutting the face.

(7) Use the simplest construction methods that will meet the tactical and technical requirements.

(8) Select the machines that perform given tasks most efficiently with fewest problems in operation and management. Chapter 2 will serve as a guide to such selection. Whenever possible, avoid the use of

technical or complicated processes requiring highly specialized equipment.

(9) Take full advantage of the technical abilities of specialists. Assign unskilled laborers only to tasks for which equipment is not available or to construction teams where they can increase the output of equipment.

(10) Make tests at the work site to solve problems in excavating and handling special materials such as coral (fig. 176), caliche, volcanic cinders, and iron ore.

(11) In the development of construction facilities and the selection of construction methods and equipment, pay special attention to unusual conditions in topography, soils and geology, drainage, and vegetation.

(12) Make the schedule flexible to meet changing site, weather, and tactical conditions. Flexibility can be introduced by selecting alternate sites for quarries, gravel pits, borrow pits, central mixing and storage plants, equipment parks and repair sections, and by keeping in mind alternate construction methods and procedures.

c. Procedure. A definite and logical planning procedure makes it possible to apply all these guiding principles. The following procedure is suggested:

(1) Make a sketch map of the work site and a large work estimate sheet. (See table LIX.)

(2) List on a separate sheet the field tests necessary to determine equipment output, the best methods of handling special materials, and proper equipment for various work items and tasks.

(3) List in sequence down the left side of the work estimate sheet all work items and tasks, including building and operating construction facilities, and aids and field tests requiring equipment and labor. (See table LIX.)

(4) Enter dates on which stages or tasks must be complete.

(5) Take quantities for each work item from the quantity survey and enter them on the work estimate sheet.

(6) List pieces of equipment best adapted for each work item to the right of that item.

(7) (*a*) Enter the estimated work output of each piece of equipment on the work estimate sheet. The estimated output of each piece of equipment is determined by work output formulas, by average tables of work output (ch. 5), or by reference to equipment performance records compiled by the unit on previous projects. Output is estimated in the standard units for a given item.

(*b*) The output of construction teams depends on the output of their key piece of equipment. Equipment and labor assigned to each team are balanced to develop full output of the key piece of equipment and to insure no waste of equipment or labor. For example, in the case of a power-shovel excavating team the following steps are necessary:

1. Estimate hourly output of shovel in cubic yards.

2. Using haul formula, paragraph 33a (5), and average length of haul, compute number of trucks required.

3. Estimate number of dozers or graders required to spread the dumped material.

4. Estimate number of rollers required to compact the spread material.

(8) Enter time needed to complete each work item in the work estimate sheet. (See table LIX.) The number of hours or days required to complete a work item with a specific piece of equipment or construction team is calculated by the following formula:

$$\text{Time required} = \frac{\text{Work quantity (total cubic yards, square yards, or other units)}}{\text{Estimated work output per piece or per team in units per hour or per day}}$$

(9) To obtain the total man-hours required (table LIX) for work items performed entirely by hand labor, multiply the work quantity by the estimated rate of performance in man-hours per work unit. Man-hours required by construction teams are estimated on the basis of records of team output and the components of the team. Estimated rates of performance for various work items are obtained from chapter 5, or from performance records compiled by the unit.

(10) (*a*) Assign available equipment and labor to the various work items and tasks so each item can be completed in accord with the guiding principles set forth in paragraph 100b.

(*b*) Expedient use of other available equipment, or of hand labor, is made when the total number of hours required of a particular machine, such as a dozer, for a given work item exceeds the number of machine hours available to that item.

(11) Balance, adjust, and coordinate schedules until the requirements for all tasks are met in accord with the guiding principles.

101. PREPARATION OF SCHEDULES. The assignments of equipment and labor made on the work estimate sheet are summarized on the construction-operations schedule. Equipment, labor, and materials schedules are prepared to supplement the construction-operations schedule.

a. Types of construction-operations schedules. Suggested types of construction-operations schedules are shown in figures 177, 178, and 179.

(1) The type of chart shown in figure 177 lists work items in sequence. Ticks on the bar of scheduled progress form a percentage scale, indicating the dates on which 25, 50, 75, and 100 per cent of the total work should be complete. The bar of actual progress is posted daily immediately under the bar of scheduled progress, and shows the percentage of the work actually complete. If on a given day work is up to schedule, the bar of actual progress will extend to that date, if behind schedule it will not extend to that date, and if ahead of schedule it will extend beyond the date. For example, in figure 177, drainage is 2 days behind schedule, clearing and grubbing is up to schedule, and stripping and excavation are each 1 day behind schedule. Actual progress is obtained from progress records, see paragraph 105.

(2) The type of chart shown in figure 178 is constructed by preparing a coordinate sheet with percent of work done on the vertical scale and dates on the horizontal scale. Estimated progress of each work item is plotted by a broken line, while actual progress is shown

Table LIX. Work estimate sheet

Stage				Work item		Equipment					Labor[1]		
		Time allotted							Assigned			Assigned	
No.	Description	Start	Finish	Description	Quantity	Piece	Hourly output	Hours	Number	Days[2]	Man-Hours	Number	Days[3]
1	Fighter strip: 4,000-ft strip cleared to 500-ft width, plus 100-ft aisles each side for waste material	6 June	30 June	Clearing and grubbing, heavy	112 acres	Tractor with dozer	0.1 acre	1,120	6	11	1,120	10	11
				Stripping, 6 to 18 inches deep	93,000 cu yd	Tractor with dozer Tractor with scraper Grader, motorized	50 cu yd 70 cu yd (5)	800 760 200	4 4 1	11 11 11	none		
				Drainage	(4)	Tractor with dozer Power shovel, ¾-cu yd Dump truck	(4) (4) (4)	190 40 340	1 1 6	13 4 4	2,700	16	18
				Excavation, dozer and scraper	120,000 cu yd	Tractor with dozer Tractor with scraper	40 cu yd 60 cu yd	960 1,400	4 9	12 9	300	3	10
				Excavation, power shovel	27,000 cu yd	Power shovel, ¾-cu yd Dump truck	70 cu yd 10 cu yd	400 2,700	2 14	12 12	none		
				Spreading and compacting	147,000 cu yd	Tractor with dozer Grader, motorized Roller, sheep's-foot	(5) (5) (5)	220 220 220	1 1 1	12 12 12	none		
				Fine grading	150,000 sq yd	Grader, motorized Tractor with scraper Roller, tandem or 3-wheel	500 sq yd (5) (5)	300 150 300	2 1 2	8 8 8	800	10	8
				Haul roads	(4) (4)	Tractor with dozer Tractor with scraper	( ) ( )	70 40	2 1	2 2	none		

See footnotes at end of table.

Table LIX. *Work estimate sheet—Continued*

Stage				Work item		Equipment					Labor[1]		
		Time allotted							Assigned			Assigned	
No.	Description	Start	Finish	Description	Quantity	Piece	Hourly output	Hours	Number	Days[2]	Man-Hours	Number	Days[3]
2	Bomber strip: stage 1, plus an additional 3,000 ft of strip, 75-ft shoulders each side, and 500- by 500-ft alert apron at each end	1 July	10 July	Clearing and grubbing, heavy	48 acres	Tractor with dozer	0.1 acre	480	5	6	480	8	6
				Stripping, 6 to 18 inches deep	55,000 cu yd	Tractor with dozer	50 cu yd	500	5	6	none		
						Tractor with scraper	70 cu yd	430	4	6			
						Grader, motorized	[5]	110	1	6			
				Drainage	[4]	Tractor with dozer	[4]	80	1	5	1,200	15	8
						Dump truck	[4]	150	2	5			
				Excavation, dozer and scraper	56,000 cu yd	Tractor with dozer	40 cu yd	530	5	6	none		
						Tractor with scraper	60 cu yd	600	5	7			
				Excavation, power shovel	16,000 cu yd	Power shovel, ¾-cu yd	70 cu yd	240	2	7	200	3	7
						Dump truck	10 cu yd	1,600	14	7			
				Spreading and compacting	72,000 cu yd	Tractor with dozer	[5]	120	1	7	none		
						Grader motorized	[5]	120	1	7			
						Roller, sheep's-foot	[5]	120	1	7			
				Fine grading	165,000 sq yd	Grader, motorized	500 sq yd	330	2	9	630	7	9
						Tractor with scraper	[5]	165	1	9			
						Roller, tandem or 3-wheel	[5]	330	2	9			

3	Airdrome facilities: stage 2, plus 6,800 ft of taxiways, one additional 500- by 500-ft alert apron, service areas, hard standings, access roads, radio beacon, direction finder, and approach clearance areas	11 July	29 July	Clearing and grubbing, heavy	113 acre	Tractor with dozer	0.1 acre	1,130	6	11	1,130	10	11
				Stripping, 6 to 18 inches deep	23,000 cu yd	Tractor with dozer	50 cu yd	200	2	6	none		
						Tractor with scraper	70 cu yd	190	2	6			
						Grader, motorized	(5)	100	1	6			
				Drainage	(4)	Tractor with dozer	(4)	200	1	14	2,800	20	14
						Dump truck	(4)	340	2	10			
				Excavation, dozer and scraper	24,000 cu yd	Tractor with dozer	40 cu yd	240	4	4	100	3	4
						Tractor with scraper	60 cu yd	240	4	4			
				Excavation, power shovel	7,000 cu yd	Power shovel, ¾-cu yd	70 cu yd	100	2	3	none		
						Dump truck	10 cu yd	700	14	3			
				Spreading and compacting	31,000 cu yd	Tractor with dozer	(5)	70	1	4	none		
						Grader, motorized	(5)	70	1	4			
						Roller, sheep's-foot	(5)	70	1	4			
				Fine grading	90,000 sq yd	Grader, motorized	500 sq yd	180	2	5	500	10	5
						Tractor with scraper	(5)	90	1	5			
						Roller, tandem or 3-wheel	(5)	90	1	5			

[1] Does not include equipment operators or crews.
[2] Based on 18-hour equipment-day.
[3] Based on two 10-hour shifts per day.
[4] Detailed break-down of quantities and equipment output not included.
[5] Component of construction team; assignment based on key piece of equipment.

by a solid line for comparison. When a job is broken down into several stages, a chart is necessary for each stage.

CONSTRUCTION SCHEDULE AND
PROGRESS CHART (PROGRESS AS OF 16 JUNE)

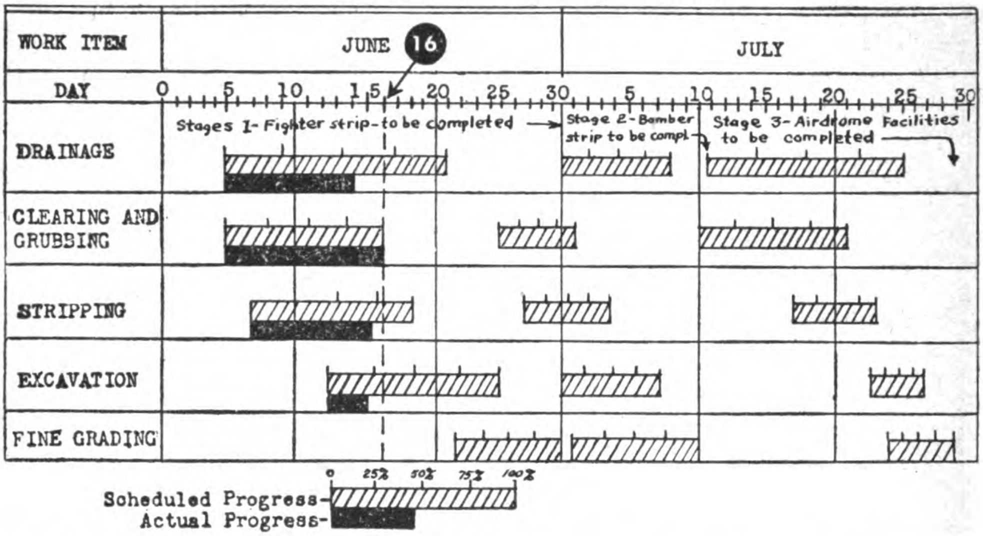


Figure 177. Construction-operations schedule and progress chart as of 16 June.

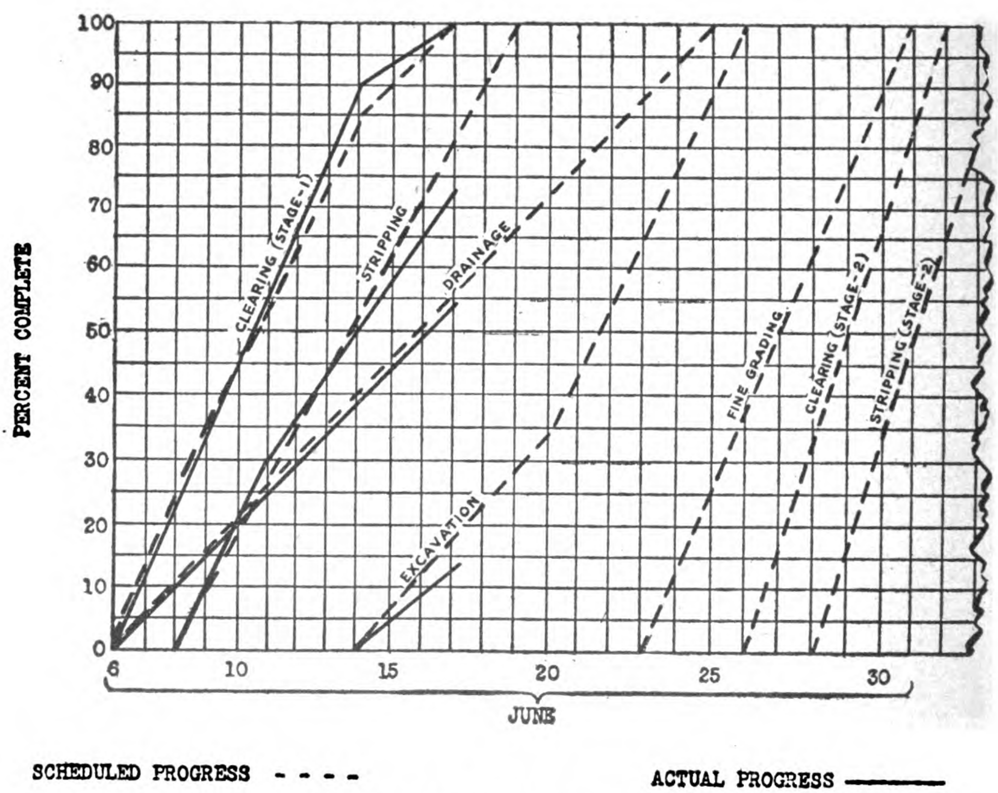


Figure 178. Construction-operations schedule and progress chart as of 16 June.

(3) The type of chart shown in figure 179 differs from that described above in that the horizontal scale shows percent of time allowed for each work item. A scale of actual dates may also be inserted on the horizontal scale. This type of chart requires a separate set of coordinates for each work item in each stage.

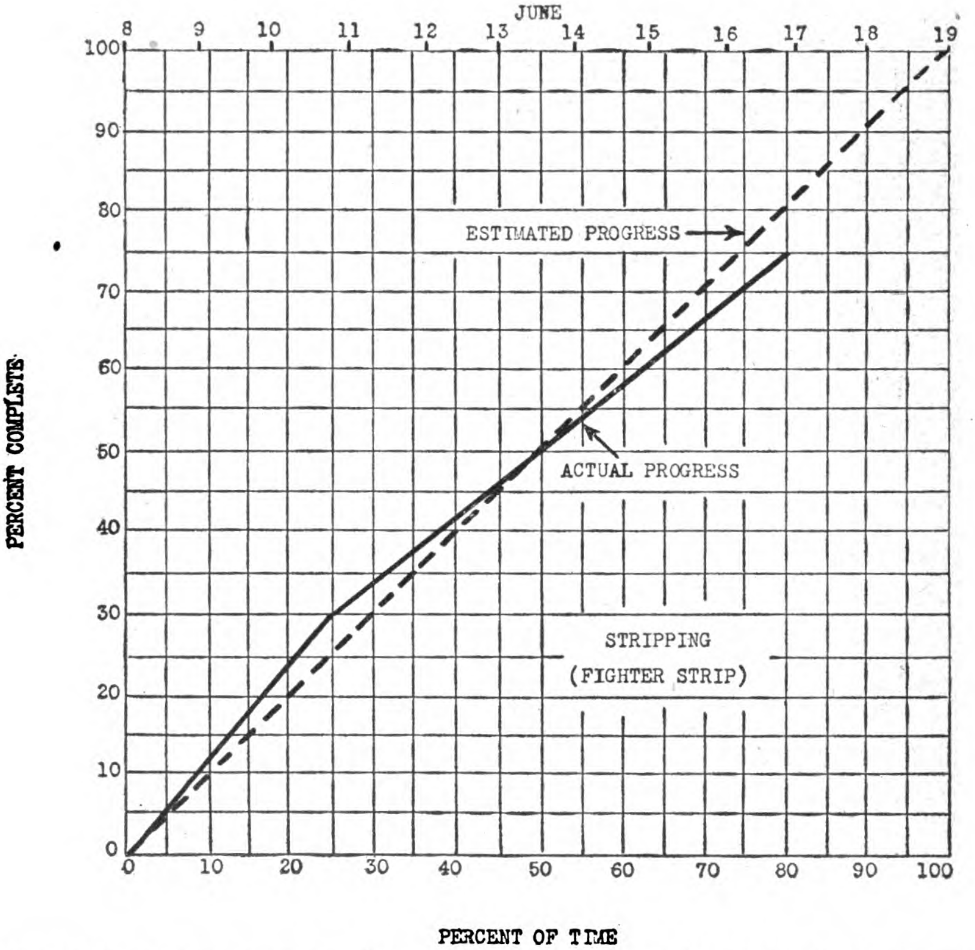


Figure 179. Construction-operations schedule and progress chart for individual work item.

b. Equipment schedule. (1) *Purpose.* The equipment schedule makes it possible to determine in advance the daily equipment requirements for all work items.

(2) *Adjustments.* When one work item is ahead of schedule and another behind, equipment should be shifted to balance work output.

(3) *Expedient use of equipment.* Expedient or secondary uses of equipment are considered when setting up equipment schedules. If a piece of equipment is no longer needed in its primary use, it may be transferred to work where it will serve as an expedient.

(4) *Typical schedule.* A suggested type of equipment schedule is shown in table LX.

c. Labor schedules. (1) *Purpose.* The labor schedule makes it possible to determine in advance the daily labor requirements for all

Table LX. Equipment schedule

Piece of equipment	Work item	Number of units required																								
		June																								
		6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
TRACTORS		16	16	14	14	14	14	14	14	15	15	15	18	16	17	17	19	19	19	19	19	16	16	16	16	16
DOZERS	Clearing	12	12	5	5	5	5	5	5	3	3	3										15	15	10	10	10
	Stripping			4	4	4	4	4	4	4	4	4	4	4										5	5	5
	Drainage	1	1	1	1	1	1	1	1	1	1	1	1	1												
	Excavation									1	1	1	1	1	5	5	7	7	7	7	7					
	Spreading									1	1	1	1	1	1	1	1	1	1	1	1					
	Haul roads	2	2																							
SCRAPERS	Stripping			4	4	4	4	4	4	4	4	4	4	2												
	Excavation												6	6	10	10	10	10	9	9	9					
	Fine grading																		1	1	1	1	1	1	1	1
	Haul roads	1	1																							
SHEEP'S-FOOT ROLLERS	Compacting									1	1	1	1	1	1	1	1	1	1	1	1					
GRADERS	Stripping			1	1	1	1	1	1	1	1	1	1	1												
	Spreading									1	1	1	1	1	1	1	1	1	1	1	1					
	Fine grading																		2	2	2	2	2	2	2	2
POWER SHOVEL, ¾-cu yd	Excavation									2	2	2	2	2	2	2	2	2	2	2	2					
	Drainage				1	1	1	1																		
ROLLER, TANDEM	Fine grading																		1	1	1	1	1	1	1	1
ROLLER, 10-TON	Fine grading																		1	1	1	1	1	1	1	1
DUMP TRUCKS	Drainage				6	6	6	6																		
	Excavation									14	14	14	14	14	14	14	14	14	14	14	14					

work items. Because equipment operators and crews go with their equipment, they are not included in labor schedules. Administrative, supervisory, and maintenance personnel are provided by established tables of organization.

(2) *Labor build up.* Labor is gradually built up to full force during the first few days of an operation and gradually tapered off during the last few days. Normally, all work sites are not available or accessible on the first day of the job and the rate at which the labor force can be expanded depends on how rapidly these sites can be made available. As the job nears completion, some work items will be completed, permitting a reduction of labor. The labor schedule is an effective tool for cutting to a minimum wasted labor resulting from this necessary build up and taper off.

(3) *Adjustment.* The shifting of labor from one work item to another is made after a study of the labor schedule.

(4) *Types of schedules.* Suggested types of labor schedules are shown in table LXI and figure 180. These schedules show the total labor required for each day and the distribution of labor by work items.

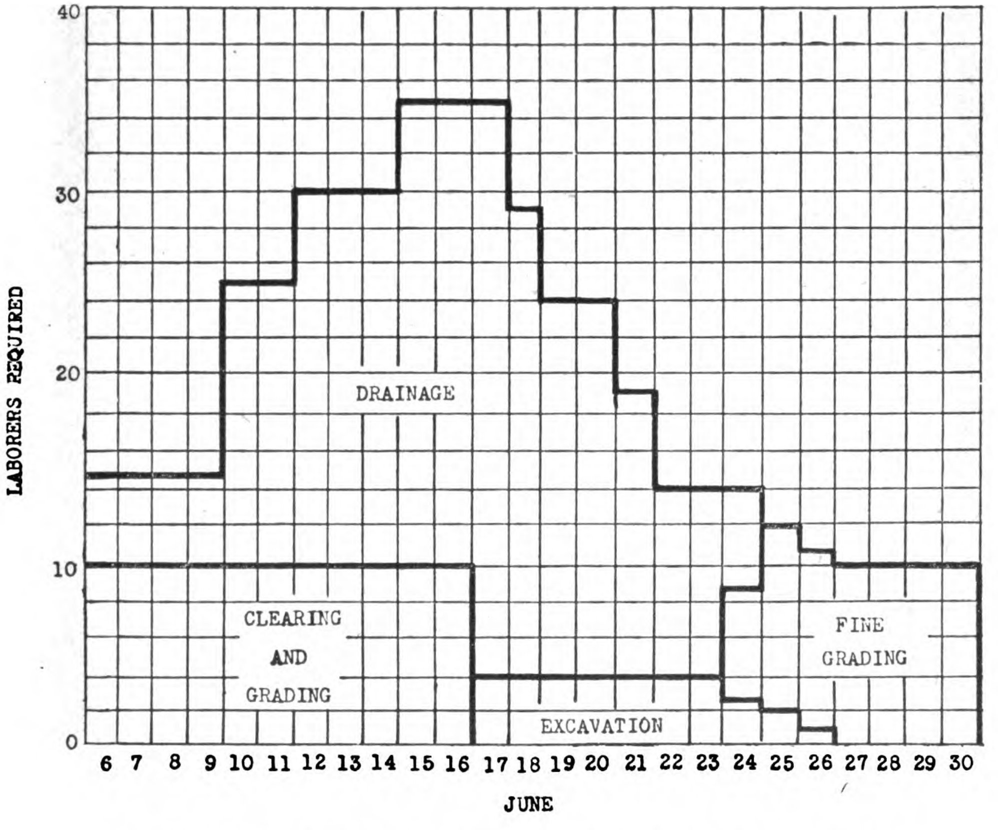


Figure 180. Schedule of labor requirements for fighter strip—stage 1.

d. Materials schedule. (1) *Purpose.* The materials schedule coordinates the preparation, delivery, and use of materials. The operation of aggregate plants, concrete-mixing plants, bituminous-materials

Table LXI. Schedule of labor requirements (fighter strip—stage 1)

Work item	Number of laborers required — June																								
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Clearing and grubbing	10	10	10	10	10	10	10	10	10	10	10														
Stripping	None																								
Drainage	5	5	5	15	15	20	20	20	25	25	25	25	20	20	15	10	10	5							
Excavation												4	4	4	4	4	4	3	2	1					
Spreading and compacting	None																								
Fine grading																		6	10	10	10	10	10	10	10
Totals	15	15	15	25	25	30	30	30	35	35	35	29	24	24	19	14	14	14	12	11	10	10	10	10	10

Table LXII. Schedule showing estimated material requirements

Material	Total quantity	Daily requirements																													
		March																													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
CONCRETE	(1,000 cu yd)																														
Cement	6,000 sacks	300	300	480	480	480	480	480					600	600	300	300	300	300				150	150	150	150						
Fine aggregate	500 cu yd	25	25	40	40	40	40	40					50	50	25	25	25	25				12	12	12	12						
Coarse aggregate	750 cu yd	40	40	60	60	60	60	60					75	75	40	40	40	40				18	18	18	18						
Water—mix	32 (1,000-gal)	2	2	2	2	2	2	2					3	3	2	2	2	2				1	1	1	1						
—curing	100 (1,000-gal)		1	2	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	2	1	
SURFACE TREATMENT																															
MC-1 (prime coat)	70 tons			10	10	10	10	10	10	10																					
MC-3 (binder coat)	100 tons												10	10	10	10	10	10	10	10	10	10									
MC-3 (seal coat)	70 tons																								10	10	10	10	10	10	10
Aggregate (binder coat)	800 cu yd												80	80	80	80	80	80	80	80	80	80									
Aggregate (seal coat)	420 cu yd																								60	60	60	60	60	60	60

plants, quarries and gravel pits, and the size and location of storage bins and stock piles are all determined by the materials schedule.

(2) *Typical schedule.* A suggested type of materials schedule is shown in table LXII.

Section III. SUPERVISION

102. ELEMENTS OF SUPERVISION. The section tells how to supervise an improved road or airdrome construction project. Effective supervision is attained by—

a. Organizing personnel.

b. Inspecting operations, personnel, equipment, and materials.

c. Maintaining adequate progress records to locate bottlenecks.

d. Continuously adjusting assignments to eliminate bottlenecks.

e. Maintaining morale. (See par. 89a.)

f. Maintaining equipment.

103. ORGANIZATION. Organization of the unit or units assigned to carry out the construction-operations schedule should conform to the approved tables of organization unless deviation is justified by unusual conditions.

a. Organization chart. An organization chart must be prepared to define clearly the responsibilities of all staff personnel and sub-units in the construction schedule. The organization chart should be posted for the guidance of all concerned.

b. Changes in organization. Changes in organization made as the job progresses must be defined clearly for the benefit of all personnel or units concerned.

104. INSPECTION. a. Planning. Personal inspections should be planned with a definite mission. The inspection must answer one or more of three basic questions:

(1) Are approved plans and specifications being followed?

(2) Is equipment and labor being used most efficiently?

(3) Are officers, enlisted personnel, and civilian laborers giving their best efforts?

b. Check lists. Check lists are used whenever possible to make certain that inspections are thorough and that time is not wasted on unimportant details.

(1) Check lists are made up from the project designs covering basic work items to determine if plans and specifications are being followed. A sample list for checking base-course construction is shown in table LXIII.

Table LXIII. Inspector's check list

INSPECTOR'S CHECK LIST

CONSTRUCTION OF SELECTED MATERIAL BASE COURSE

1. Is subgrade
   a. well compacted?
   b. true to grade?
   c. true to cross section?

2. Is delivery of base material being made
   a. on schedule?
   b. at an even rate?

3. Does method hauling
   a. prevent segregation of fine and coarse material?
   b. aid in compaction of base by proper routing of equipment?

4. Is material
   a. of specified size?
   b. of specified quality?
   c. of specified grading?

5. Is material being spread
   a. uniformly?
   b. to required depth?

6. Are rollers compacting material
   a. uniformly?
   b. to required degree of compaction?
   c. at optimum moisture content?

7. Is finished surface
   a. true to grade?
   b. true to cross section?
   c. free from pockets of ungraded material?
   d. being maintained free from ruts?

(2) Check lists for proper operation and management of individual pieces of road and airdrome construction equipment are given in chapter 3.

(3) Management check lists are useful in coordinating all operations relating to equipment, labor, and materials. (See par. 106.)

105. PROGRESS RECORDS. a. Purpose. Progress records measure the work which has been accomplished on a project. These records have a threefold purpose:

(1) To determine whether or not the work is being performed at the estimated rate.

(2) To analyze equipment performance for possible improvements.

(3) To establish a basis for estimating future projects.

b. Progress charts. The separate work progress chart shown in figure 181 is advantageously used on projects covering a large area, such as a long road. Daily entries show the stage of completion of various work items at different work sites. The chart consists of a lay-out of the road or airdrome, including all structures and construction plants. Completion of a work item on the lay-out is indicated by an appropriate hatching or color.

c. Work output records. Work output records are divided into two general types: records showing the total number of hours or days required to complete a work item of known dimensions with a given amount of equipment and personnel; and records showing the work output of construction teams or individual pieces of equipment on specified work items.

(1) Table LXIV shows a suggested method of recording the work output of a construction team in terms of average number of units per hour.

(2) Table LXV shows a suggested method of tabulating work completed, total time required, equipment and labor used, and explanatory

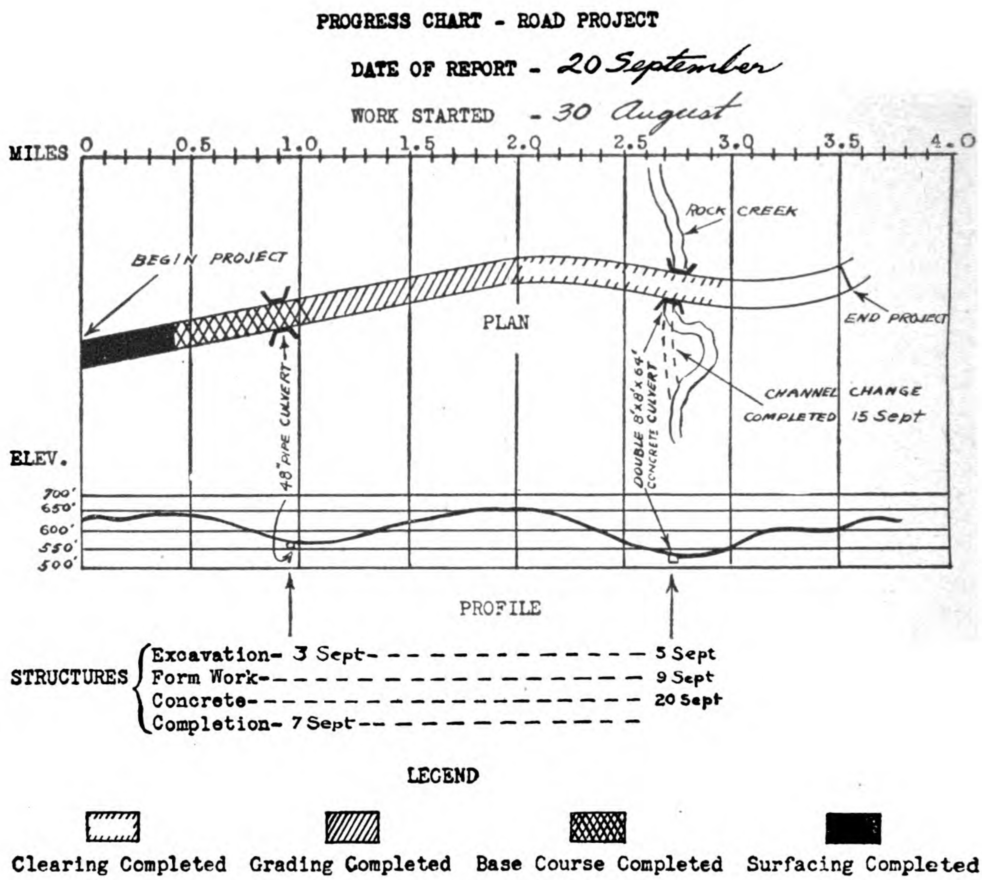


Figure 181. Work progress chart for improved-road construction project. Cross hatching, indicating status of different work items, is brought up-to-date daily.

remarks for the over-all type of record covéring all work items on a project.

Table LXIV. Work output report

WORK ITEM *Excavation (cu. yd.)* TEAM NO. *Scraper Team No. 1*

Team components	Dates	Team output			Remarks
		Total	Daily	Hourly	
2—D8 tractors towing 12-cu yd scrapers. 1—D8 tractor with dozer (pusher) 1—TD18 tractor with dozer and sheep's-foot roller at dump. 4—Laborers	17 June to 25 June	20,000	2,220	150	Material soft coral, no rooting required. Two 9-hour shifts worked per day, but rains caused average loss of 3 hours per day in work time. Average length of haul was 750 feet over good haul roads.

Table LXV. Work output record

Location: *Airdrome, stage 1—fighter strip* Date: *6 June to 30 June*

Work item	Total quantity	Equipment					Labor				Remarks
		Piece	Avg. No.	No. days	Hr. per day	Avg. hourly output per piece	Type	Avg. No.	No. days	Hr. per day	
Clearing and grubbing	112 acres	D8 tractor with dozer.	7	11	15	0.1 acre	Troop Native	5 5	11 11	9 9	Heavy jungle growth, many large trees, soft ground. Rains hindered but did not stop work.
Stripping	93,000 cu. yd.	TD18 tractor with dozer.	5	11	17	45 cu. yd.	Troop Native	0 0			Depth from 6 to 18 inches. Rain caused average delay of 1 hour a day. No rooting required. Average haul for scrapers 800 feet, for dozers 150 feet.
		D8 tractor and 12-cu.yd. scraper.	5	11	17	55 cu. yd.					
		Grader	2	5	17	[1]					
Excavation (dozer and scraper).	120,000 cu. yd.	TD18 tractor with dozer.	5	12	15	40 cu. yd.	Troop Native	4 0	8	10	Excavation consisted entirely of coral, little rooting required. Rains caused considerable shutdown and delay.
		D8 tractor and 12-cu.yd. scraper.	10	8	15	70 cu. yd.					
		D8 tractor with dozer.	2	8	15	[1]					
Excavation (power shovel)	27,000 cu. yd.	D8 tractor and dozer.	1	10	18	[1]	Troop Native	0 0			Shovel excavation delayed by lack of sufficient trucks to handle output.
		Power shovel, ¾-cu. yd.	2	12	18	62 cu. yd.					
		Dump truck	14	12	18	9 cu. yd.					

[1] Supplemental member of construction team, output measured for key piece.

Table LXVI. Weekly project equipment-use report

Working		Standby	S	Under Repair	R

	Date and shift													
	17 June		18 June		19 June		20 June		21 June		22 June		23 June	
Piece of equipment	1st	2d	1st	2d	1st	2d	1st	2d	1st	2d	1st	2d	1st	2d
Tractor No. 1					S			R	R	R				
Tractor No. 2												S		
Tractor No. 3	S	S												
Grader No. 1					R	R								
Grader No. 2	S	S	S	S			S	S						

(3) Quantities are determined either by machine loads, as for power shovels and scrapers, by measurements of lay-outs, profiles, cross sections, and mass curves, or from field surveys.

d. Equipment records. Details of equipment use and work output are provided by the project equipment-use report and the machine operator's shift report.

(1) A project equipment-use report is shown in table LXVI. Each piece of equipment is entered in the first column and dates of operation are entered in the next column. The box for each date is split into two parts to accommodate the two shifts. Appropriate symbols indicate whether the equipment was working, standing by, or under repair during each shift.

(2) Table LXVII shows a suggested operator's shift report for tractor-drawn scrapers. Shift reports for other individual pieces of equipment are prepared similarly.

e. Use of progress and work output records. (1) *For supervision.* Progress and work output records are compared with work items, equipment, labor, and materials schedules, and construction estimates. From such comparison it is possible to determine whether schedules are being followed and estimated work output attained. If not, the bottleneck should be located and performance on all work items balanced.

(2) *For reports.* Progress and work output records provide a basis for progress reports to higher headquarters.

106. BOTTLENECKS. a. Definition. A bottleneck is a controlling factor or feature of a work item or project which causes work output to drop below normal.

Table LXVII. Shift report

SHIFT REPORT

SHIFT NO. *2* DATE *19 June 44* WORK ITEM *Excavation*
EQUIPMENT *Tractor-Scraper No. 3* STARTING TIME *1400* OPERATOR *Smith*

Hour	Working minutes	No. trips	Haul	
			From	To
1	50	5	Sta 5 + 00	Sta 12 + 00
2	50	5	Sta 5 + 00	Sta 12 + 00
3	50	6	Sta 5 + 00	Sta 12 + 00
4	30	3	Sta 5 + 00	Sta 12 + 00
5	30	3	Sta 5 + 00	Sta 12 + 00
6	50	6	Sta 6 + 00	Sta 14 + 00
7	0	0		
8	0	0		
9	50	6	Sta 6 + 00	Sta 14 + 00
10	40	4	Sta 6 + 00	Sta 14 + 00
11				
12				
Totals	350	38		

Remarks: Loads heaped. Rain during hours 7 and 8.

b. Causes. Bottlenecks may be caused by the performance of equipment or labor, shortages of materials, or poor construction methods.

c. Remedy. Eliminating bottlenecks means essentially balancing performances. When an operation is ahead of schedule, it is usually using labor or equipment which should be assigned to an operation behind schedule. The information needed to balance work is obtained by careful review and analysis of schedules, progress charts, work output records, and equipment records, and by field inspection.

d. Equipment. In the construction of improved roads and airdromes, bottlenecks are often caused by improper assignment and use of equipment. The officer in charge should take full advantage of the information in chapters 2 and 3. Field tests should be made to determine the capacity of machines in unusual materials. The project equipment-use record and the shift reports prepared by equipment operators should be carefully reviewed and analyzed. From this information and by personal inspections, the officer in charge should be prepared at all times to answer the following questions regarding each key piece of equipment:

(1) Is it giving maximum work output under existing conditions?

(2) Could it be employed to better advantage at another location

or on another task? For example, a power shovel side-casting from a sidehill cut might be moved to a deep cut where haul is required and be replaced by an angledozer.

(3) Could more output be obtained on the same task from another available machine? For example, a dozer pushing soil to a fill 400 feet away probably should be replaced by a tractor-drawn scraper.

(4) Can its output be increased materially by adding supplemental labor or equipment? For example, the output of a tractor-drawn scraper working in a heavy soil might be greatly increased by adding a pusher tractor.

(5) Can its output be increased materially by using construction aids such as chutes and traps for loading trucks with a bulldozer?

(6) Can its output be increased by improving construction facilities; for instance, by smoothing haul roads or sprinkling to settle dust?

(7) Is the construction team correctly balanced? For example, should more dump trucks be added to the power-shovel team? Are trucks now waiting in line?

(8) Is inadequate lighting slowing down night operations?

(9) Is the machine being properly and rapidly serviced? Is first echelon repair being performed promptly?

(10) Are operators fully aware of their responsibilities and have they been properly trained in the type of work they are now doing?

e. Labor. Labor schedules and work output records should be carefully reviewed and analyzed. All crews should be inspected and observed. Using information obtained from these sources, the officer in charge should be able to answer the following questions:

(1) Is each crew giving maximum output under existing conditions?

(2) Could part or all of the crew be employed to better advantage on another task?

(3) Can the labor be replaced by an available piece of equipment? For example, laborers shaping and finishing a side ditch can be replaced by a blade grader.

(4) Can output of the crew be increased by adding more hand tools or equipment? For example, pneumatic tampers are usually more efficient than hand tampers.

(5) Do the crew foremen know their jobs and are they keeping the men working at full capacity?

(6) Is civilian labor being used to best advantage? That is, is too much or too little civilian labor being used, is it distributed properly among troops, is it assigned to proper tasks, is it using procedures at which it is most efficient?

f. Materials. Requirement, production, and delivery schedules for materials must be reviewed and analyzed. Field tests must be made to determine the quality and condition of materials, and field inspections must be conducted to see if they are being properly handled. Using information obtained from these sources, the officer in charge should be able to answer the following questions:

(1) Is overburden being removed from quarries and pits properly and efficiently?

(2) Are proper methods being used to remove material from quarries and pits and is the material of satisfactory quality?

(3) Are crushing, screening, and washing plants, and concrete and

bituminous-materials mixing plants being operated properly and efficiently? Do the plants need additional equipment or personnel?

(4) Are correct hauling methods being used and is the proper type and amount of equipment assigned to the work?

(5) Are stock piles located advantageously, are they large enough, are they properly policed?

(6) Is adequate supplemental equipment such as batching bins and trucks, clamshells, bucket loaders, and elevators available?

107. EQUIPMENT MAINTENANCE AND OPERATORS. An initial and continuous responsibility of supervision and management is to train equipment operators and to check the maintenance of all equipment.

a. Equipment operators. Operators should know how to handle their machines and should understand their correct use and application as outlined in this manual. Thorough training, testing, and supervision of operators will increase production.

b. Maintenance of the unit. Each piece of equipment must be in good working condition if schedules are to be met. This requires that all drivers, operators, and supervisors be familiar with first echelon repair and preventive maintenance as given in the appropriate Technical Manuals for each unit of equipment. Frequent command inspections, periodic technical inspections, and regular and systematic second echelon maintenance are necessary. All personnel who are drivers, operators, mechanics, or supervisors must study FM 25–10 and TM 38–250. The need for daily motor inspection and servicing and thorough weekly inspection cannot be overstressed. Traveling service units furnish oil, grease, air, water, and gasoline to equipment on the job. (See fig. 182.)

Figure 182. Air compressor being serviced on the job by a truck-mounted service unit. Gasoline is being delivered from barrels on the front of the truck. The skid-mounted lubricator unit is on the rear of the truck.

CHAPTER 7

PIONEER ROADS AND ADVANCED LANDING FIELDS

Section I. GENERAL CONSIDERATIONS

108. PURPOSE. This chapter tells how to manage the construction of pioneer roads and advanced landing fields.

109. GENERAL. The construction of pioneer roads and advanced landing fields differs from the construction of improved roads and airdromes for the following reasons.

a. They are temporary in nature and limited to technical essentials.

b. They are built with the utmost economy of time, labor, materials, and transportation.

c. Construction is done with equipment on hand and immediately available.

d. They require readiness and ability to improvise and substitute.

110. MISSION. The mission of building a pioneer road or advanced landing field is given in an oral or written directive. The directive states the time allotted, the location, and the anticipated type and density of traffic.

111. ORGANIZING THE JOB. Immediate steps taken by the officer in charge to organize the job are listed below in their proper order.

a. Bring equipment, troops, and materials to the site.

b. Start work immediately on available tasks.

c. Make a personal construction reconnaissance.

d. Prepare a simple construction-operations schedule.

e. Reassign labor and equipment to conform to the schedule.

112. CONSTRUCTION SUPERVISION. Close supervision by the officer in charge and his assistants is necessary to keep the work on schedule. An unexpected delay on one phase of the work is offset by shifting labor and equipment from other assignments which are ahead of schedule or are of less importance. The work must progress on schedule and at a uniform rate.

Section II. PIONEER ROADS

113. GENERAL. This section tells how to plan, estimate, and schedule labor, equipment, and materials for the construction of pioneer roads.

114. CONSTRUCTION RECONNAISSANCE. A personal reconnaissance is made of the entire project which is divided into work sites easily recognizable by landmarks, such as sidehill cuts or stream crossings. A simple sketch (fig. 183) showing location, source of local materials, soil conditions, and general construction features is prepared. This sketch is helpful also when actually assigning tasks.

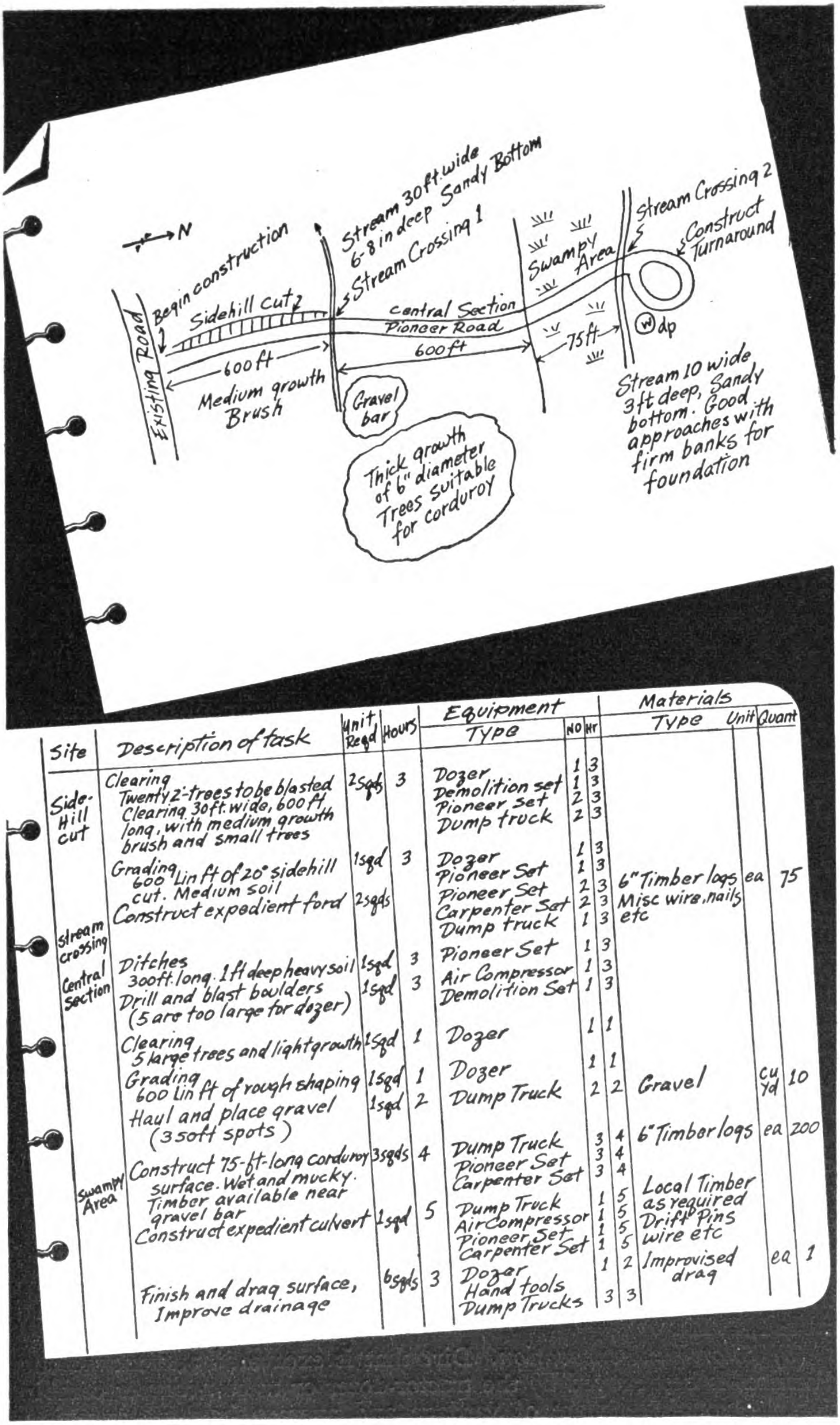


Figure 183. Construction reconnaissance sketch and work estimate sheet for pioneer road construction project.

115. ESTIMATING WORK. a. Work estimate. As the reconnaissance proceeds, a work estimate sheet (fig. 183) is prepared to supplement the reconnaissance sketch. This sheet shows the following data:

(1) Location of each task.

(2) Description of specific task, including hastily estimated quantities and dimensions.

(3) Labor, equipment, materials, and time required for each task.

b. Productive capacity of labor and equipment. Table LXVIII lists normal work output for labor and equipment based on average materials, efficient supervision and operation, and proper equipment maintenance. See chapter 5 for more detailed tables. Work output figures given should be modified where necessary to suit conditions peculiar to the job.

c. Work items. Divide the work to be done into four items:

(1) Drainage.
(2) Clearing.
(3) Grading.
(4) Surfacing.

d. Quantities. A quantity survey is made as the reconnaissance proceeds. The survey is made in the simplest possible units. Certain tasks are converted into equipment-hours or man-hours directly without estimating quantities. For example, table LXVIII shows directly the linear feet of sidehill cut that can be made per hour by a tractor-angledozer combination.

(1) *Drainage.* Drainage work is estimated for ditches, structures, and swampy or boggy areas.

(*a*) *Ditches.* Pace the length and convert to squad-hours or equipment-hours by use of table LXVIII, or estimate the depth, width, and shape, and compute the yardage to be excavated.

(*b*) *Structures.* Note dimensions, list materials and special tools required, and estimate squad-hours to construct.

(*c*) *Swampy areas.* Estimate materials required for corduroy or other expedient means of crossing and squad-hours to construct.

(2) *Clearing.* (*a*) *Classify.* Clearings are classified as light, medium, or heavy. Obtain the area by multiplying the average width by the length. See table LXVIII for estimated rate of clearing by labor and equipment.

(*b*) *Large trees.* Large trees are blasted or cut. Count or estimate the number of trees of this class, and estimate the labor and materials required to remove each tree.

(3) *Grading.* Grading is classified in terms of sidehill cut, short-haul or long-haul excavation, and shaping. Compaction does not require quantity estimation since pioneer roads are usually compacted by travel of the earth hauling and handling equipment.

(*a*) *Sidehill cut.* The length of cut is paced and ground slope in degrees is measured with clinometer or estimated. Work output of tractor-angledozer on sidehill cut in linear feet per hour is given in table LXVIII.

(*b*) *Short-haul excavation.* Dirt that is excavated and moved short distances is best moved by the tractor-dozer or tractor-scraper combination. A rough estimate of yardage and average haul distance is required before equipment-hours can be estimated.

Table LXVIII. Productive capacity of labor and equipment

Equipment	Rate-units per hour	Unit	Conditions
DRAINAGE DITCHES			
Grader, motorized	450	cu yd	**V**-ditches, light soil.
	300	cu yd	**V**-ditches, medium soil.
Hand tools	3 man-hours	100 ft	**V**-ditches, 3 feet wide, 1 foot deep, light soil.
	10 man-hours	100 ft	**V**-ditches, 3 feet wide, 1 foot deep, medium soil.
CLEARING AND GRUBBING			
Hand tools	1½ man-hours	tree	3-man blasting team, good conditions.
	125 man-hours	acre	Light clearing.
	350 man-hours	acre	Medium clearing.
	25 man-hours	100 lin yd	Light clearing, 30 feet wide.
	70 man-hours	100 lin yd	Medium clearing, 30 feet wide.
Mower with tractor, 30-dbhp.	2.0	acre	Cutting weeds and grasses.
Tractor, 66- to 90-dbhp, with dozer.	1.0	acre	Light stripping or clearing.
	0.25	acre	Medium clearing.
	20 to 50	trees	4- to 10-inch diameter.
	3 to 12	trees	12- to 30-inch diameter.
GRADING			
Tractor, 66- to 90-dbhp, with dozer	400	lin ft	Sidehill cut, medium soil, 10° slope.
	190	lin ft	Sidehill cut, medium soil, 20° slope.
	110	lin ft	Sidehill cut, medium soil, 30° slope.
	120	cu yd	Sidehill cut, medium soil.
	90	cu yd	Sidehill cut, heavy soil.
	130	cu yd	50-foot level haul, medium soil.
	80	cu yd	100-foot level haul, medium soil.
Scraper, towed, 8-cu yd, with tractor, 66- to 90-dbhp.	95	cu yd	500-foot level haul, medium soil.
	60	cu yd	800-foot level haul, medium soil.
Shovel, power, ¾-cu yd.	45	cu yd	Hard digging.
	75	cu yd	Easy digging.

Table LXVIII. Productive capacity of labor and equipment—Continued

Equipment	Rate-units per hour	Unit	Conditions
Grader, motorized	0.2	mile	Digging side ditches and shaping crown, 4 rounds.
Hand tools	1.7	cu yd	Loading loose gravel into truck, one man with shovel.

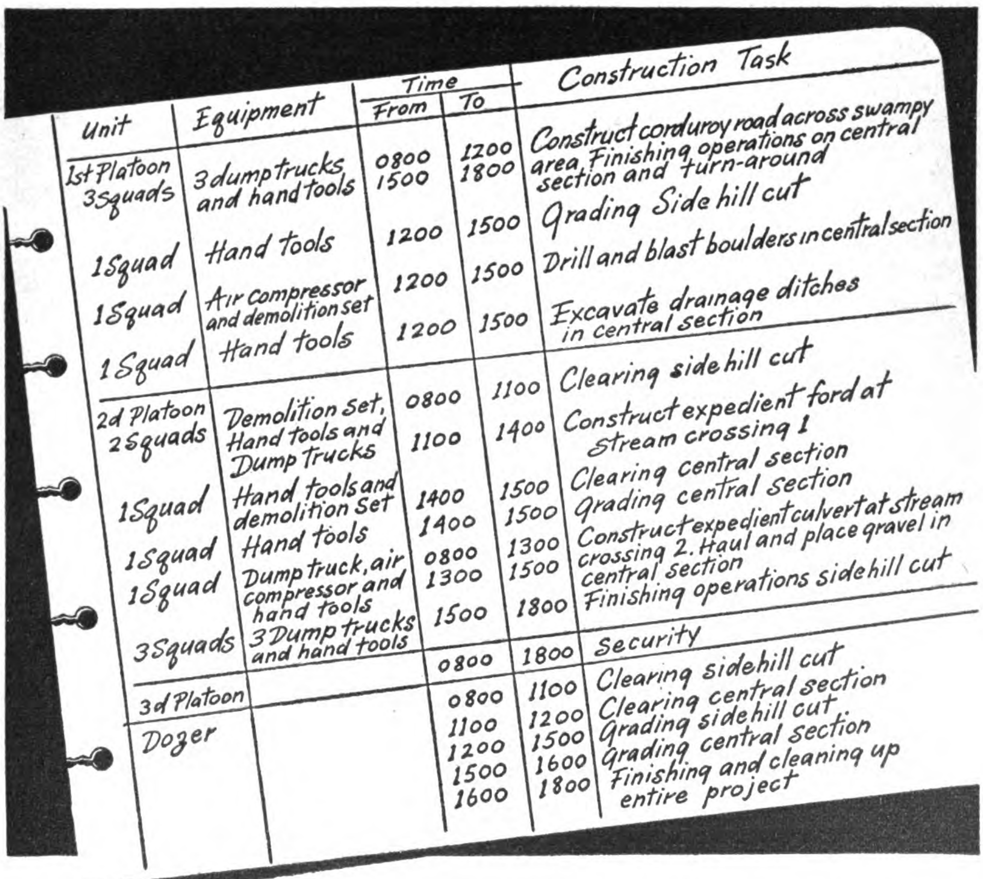
Steel Landing Mats	Average laying speed per man-hour (sq ft)	
Pierced plank	125	
Heavy bar-and-rod	65	
Irving grid	65	
Light bar-and-rod	125	
Sommerfeld	175	
Aluminum pierced plank	700	

(*c*) *Long-haul excavation.* Haul distances greater than 300 feet are avoided whenever possible in pioneer road construction. No attempt is made to balance cut and fill by long hauls. Where long hauls are required, dump trucks are used and may be loaded by dozers through traps and chutes (ch. 4) if power shovels are not available. The quantity in cubic yards and the average haul distance must be estimated before equipment requirements can be determined.

(4) *Surfacing.* Base course and surfacing are normally placed at a later date by construction units with heavier equipment. The estimate includes the yardage to be placed and the haul distance plus preparation of the material site.

116. SCHEDULING. The schedule of construction operations and the reassignment of labor and equipment to specific tasks under the schedule are made as soon as the construction reconnaissance is completed and the work estimate sheet is prepared. This is the most important phase of preliminary planning and is as detailed as time permits. A typical example of such a schedule for a pioneer road is shown in figure 184. Factors which control assignments are discussed in the following paragraphs.

a. The relative importance of all tasks must be weighed. First things must be done first, and if sufficient labor and equipment are not avail-



Unit	Equipment	Time From	Time To	Construction Task
1st Platoon 3 Squads	3 dump trucks and hand tools	0800 1500	1200 1800	Construct corduroy road across swampy area Finishing operations on central section and turn-around
1 Squad	Hand tools	1200	1500	Grading Side hill cut
1 Squad	Air compressor and demolition set	1200	1500	Drill and blast boulders in central section
1 Squad	Hand tools	1200	1500	Excavate drainage ditches in central section
2d Platoon 2 Squads	Demolition Set, Hand tools and Dump Trucks	0800 1100	1100 1400	Clearing side hill cut Construct expedient ford at stream crossing 1
1 Squad	Hand tools and demolition set	1400	1500	Clearing central section
1 Squad	Hand tools	1400	1500	Grading central section
1 Squad	Dump truck, air compressor and hand tools	0800 1300	1300 1500	Construct expedient culvert at stream crossing 2. Haul and place gravel in central section
3 Squads	3 Dump trucks and hand tools	1500	1800	Finishing operations side hill cut
3d Platoon		0800	1800	Security
Dozer		0800 1100 1200 1500 1600	1100 1200 1500 1600 1800	Clearing sidehill cut Clearing central section Grading side hill cut Grading central section Finishing and cleaning up entire project

Figure 184. Construction-operations schedule for a pioneer-road project.

able to complete all tasks within the time allotted, certain tasks will have to be eliminated. If none of the proposed tasks can be eliminated without seriously impairing the usability of the road, construct to minimum standards throughout and use expedients.

b. The controlling work item is determined and enough labor and equipment are assigned to complete it within the time allotted. Clearing and grading normally constitute the bulk of the work.

c. Remaining equipment and labor are assigned to other items. Some tasks for which ample time is available are performed entirely by hand labor, or by hand labor supplemented with expedient equipment.

d. The assignment of equipment to work items and tasks is adjusted and balanced until a schedule has been set up by which the job can be completed on time.

e. Temporary work assignments made at the time labor and equipment arrived at the work site are canceled and work is started under the new schedule.

Section III. ADVANCED LANDING FIELDS

117. GENERAL. a. This section tells how to plan and manage the construction of advanced landing fields.

b. See FM 5–255 for requirements, reconnaissance, lay-out, estimation, and construction of advanced landing fields.

118. CONSTRUCTION RECONNAISSANCE. The extent of construction reconnaissance depends on the information available in advance. The directive assigning a unit to construct an advanced landing field normally designates several alternate sites selected from aerial reconnaissance and intelligence reports.

a. Advance reconnaissance detachment. The officer in charge accompanies an advance reconnaissance detachment to the proposed sites and makes a rapid but accurate appraisal of conditions, verifying previously acquired information. Site selection is based on principles set forth in TM 5–255.

b. Lay-out and quantity survey. While the advance reconnaissance detachment prepares the lay-out and quantity survey under the personal supervision of the officer in charge, available equipment and troops are immediately ordered to the site selected.

119. SCHEDULING. a. Preliminary work. In advance areas where equipment and troops cannot reach the site over existing roads or trails, a landing strip meeting minimum requirements for transport plane operation is constructed by an advance party. This work is done entirely by hand labor and glider-borne equipment (fig. 185), and initial scheduling consists only of assigning this advance party to the most essential work. Airborne equipment is described in chapter 3.

b. Construction-operations schedule. As heavy equipment and additional labor arrive at the site, they are assigned to jobs under an operational schedule based on data obtained from reconnaissance, hasty estimates, and estimated work output of equipment. This is done in

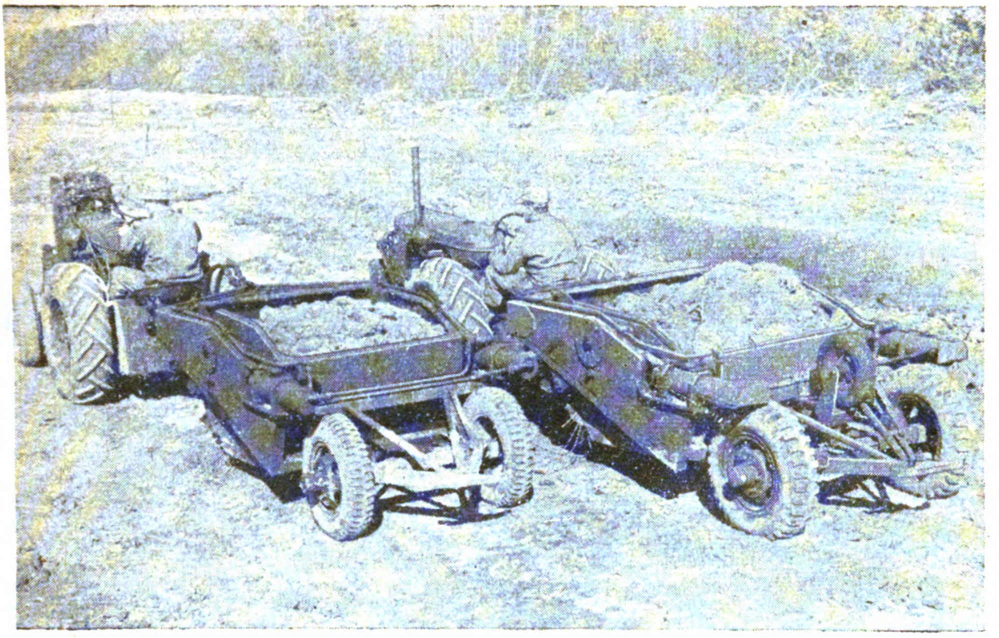


Figure 185. Airborne scrapers, hydraulically operated towed-type of 1½ cubic yard capacity, working on an advanced landing field. These scrapers are organic equipment of airborne aviation battalions.

a manner similar to that shown in figure 184. Principles outlined in chapter 3 and in section II of this chapter are followed in scheduling and supervising the job.

c. Control. Best results are obtained by placing one complete operation under the control of a tactical unit. For example, have one platoon responsible for all clearing and grubbing, another for all drainage work, and a third for grading and compaction.

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